Background Information

This appendix evaluates alternatives to reinforce the Wisconsin Public Service Corporation (WPSC) Upper West area. The Upper West area is defined as the WPSC service territory north of Wausau, Wisconsin. Figure D-1 is a depiction of the WPSC service territory with the Upper West area highlighted.

Transmission System Description

The Upper West 115 kV transmission system is primarily a 'figure eight' loop that provides service to several distribution substations spread throughout the area. Additionally, the 115 kV system directly serves one large industrial customer in Rhinelander. The distribution substations and the associated communities are listed below.

Substation(s)	Community
Aurora St.	Antigo
Venus	Monico, Crandon
Three Lakes	Three Lakes
Cranberry	Eagle River
St. Germain	St. Germain
Clear Lake	Minocqua, Woodruff
Highway 8, Hodag	Rhinelander
Eastom	Tomahawk

The Upper West 46 kV system between Tomahawk and Merrill supports several hydroelectric generating stations. The 46 kV system also directly serves a large industrial customer in Tomahawk.

The entire Upper West transmission system is supplied by three 115 kV lines emanating from the Wausau area. WPSC does have one interconnection with Alliant via a 69 kV line terminating at Aurora St. substation in Antigo. The interconnection supports Alliant's 69 kV system and provides little or no support for WPSC's system. Figure D-2 is a one-line diagram of the existing WPSC Wausau/Upper West transmission system.

Near-term Transmission System Changes

WPSC has plans for several projects to strengthen the Wausau/Upper West transmission system and provide additional distribution system sources. Those projects, with completion dates in 2000 or 2001, are listed below.

- The installation of six Distributed Superconducting Magnetic Energy Storage (D-SMES)

units at several substations in the Upper West. These devices will support transmission system voltages by rapidly injecting real and reactive power following a disturbance.
Scheduled completion date: June 2000

- Construction of a 115/24.9 kV substation on the northwest side of Wausau. Maine substation will serve distribution system load in Wausau. It will be constructed under the existing 115 kV line between the Hilltop and Pine substations.
  Scheduled completion date: June, 2000

- Construction of a 115/24.9 kV substation north of Antigo. Summit Lake substation will serve distribution system load north of Antigo. It will be constructed under the existing 115 kV line between the Aurora St. and Venus substations.
  Scheduled completion date: June, 2001

- Construction of a 115 kV transmission line between Maine substation and the Brokaw switching station north of Wausau. WPSC plans to construct a 115 kV transmission line, initially energized at 46 kV, to reinforce the urban 46 kV system in Wausau by replacing an older 46 kV line emanating from Pine substation in Merrill. The completion of this line is the first step in a plan to convert the northern 46 kV system in Wausau to 115 kV operation.
  Scheduled completion date: June, 2001

Figure D-3 is a one-line diagram of the Wausau/Upper West transmission system following the completion of these near-term projects.

Upper West Load Growth

Due to significant growth in the tourism industry, the Upper West area has seen steady growth in the residential and commercial customer sectors. Additionally, the load growth in the industrial sector has been significant as well with demand steadily increasing. This translates to increasing peak demands placed upon the Upper West transmission system. Generally, the aggregate distribution system load in the area reflects the growth in the residential and commercial customer groups, while the load directly served by the transmission system reflects the industrial load growth in the region. Figure D-4 plots historical peak load data for the Upper West distribution system customers (< 25 kV) and historical average load data for the industrial customers directly served by the transmission system (>25 kV).

Using linear regression, the historical data indicates that the total summer peak demand on the Upper West transmission system should increase at a rate of approximately 2.5% annually. Figure D-5 plots projected summer peak loads for the Upper West transmission system.

Problem Identification

As load continues to increase in the Upper West area, the transmission system will be exposed to voltage instability or voltage collapse following a single contingency. Voltage collapse occurs when the transmission system, combined with local generation, cannot provide enough reactive power to maintain adequate bus voltages in a region impacted by a system disturbance. The system voltages in a region uncontrollably fall to levels at which customer equipment is damaged or is tripped off-line by protective devices. Voltage collapse in a region can be total (blackout) or partial (brownout).

Voltage instability is a less severe condition in which a portion of the bus voltages in an area falls to unacceptable levels. Load drops off-line and over a period of time the bus voltages in the area recover. When attempts are made to restore the load, bus voltages fall again and the load trips again. The cycle will continue until transmission system operators shed load to stabilize voltages.

The reactive power requirements of the system before and after a disturbance is highly dependent upon the operating characteristics of generation and load in the region. Of particular concern is the performance of customer owned induction motors during system voltage sags. The combined impact of small induction motors used for residential refrigeration and air conditioning can be just as significant as the large industrial induction motors used in manufacturing processes.

A forced outage to the Black Brook--Aurora St. 115 kV line causes the most concern for voltage collapse. An outage to the Eastom--Highway 8 115 kV line will also cause voltage instability or voltage collapse. Figure D-6 highlights the location of each critical line segment.

WPSC will install six D-SMES units to protect the Upper West system from voltage collapse in the near term. Following a severe drop in voltage, each unit is capable of injecting 2.0 MW of real power for a duration of 0.4 seconds, 7.5 MVARs of reactive power for a duration of 1.0 second (a 250% overcurrent rating), and 3.0 MVARs of reactive power indefinitely. Based on current load projections, these devices will adequately protect the system through the 2002 summer.

Power System Dynamic Simulations

Load Models

Dynamic simulations, utilizing Power Technologies, Inc. PSS/E software, evaluated the effectiveness of the D-SMES units. Those simulations made the following load model assumptions:

- The Upper West load models at each substation were broken into dynamic (motors) and static components.
- CIMTR5 induction motor models were used to simulate the response of the dynamic (motor) components of the loads.

- The static components of the loads were split equally between constant current and constant impedance characteristics.

Table D-1 summarizes the load component breakdown / load model for each substation in the Upper West area. The distribution system load models were developed from estimated customer class breakdowns (residential/commercial/industrial) for individual feeders.

Table D-1: Distribution Load Breakdown for Dynamic Simulations.

Substation	Dynamic/Motor Load	Static Load	
		Constant Current	Constant Impedance
Aurora St.	59.4%	20.3%	20.3%
Clear Lake	56.7%	21.7%	21.7%
Cranberry	57.7%	21.1%	21.1%
Eastom	61.7%	19.2%	19.2%
Highway 8	62.9%	18.6%	18.6%
Hodag	61.3%	19.4%	19.4%
Merrill 46 kV	62.2%	18.9%	18.9%
Pine	59.7%	20.2%	20.2%
St. Germain	56.8%	21.6%	21.6%
Summit Lake	55.6%	22.2%	22.2%
Three Lakes	57.1%	21.4%	21.4%
Venus	57.1%	21.4%	21.4%

The distribution system loads were modeled at a native power factor of 90%. Power factor correction capacitors were explicitly modeled to correct the net power factor of each feeder to 100%. Figure D-7 displays a sample load model for a distribution feeder at Highway 8 substation.

The load models for facilities directly served by the transmission system were developed from information obtained from those customers. Table D-2 summarizes the load models for these customers served directly from the transmission system.

Table D-2: Transmission Customer Load Breakdown for Dynamic Simulations.

Customer Location	Dynamic/Motor Load	Static Load	
		Constant Current	Constant Impedance
Rhinelander	57.4%	21.3%	21.3%
Tomahawk	47.0%	26.5%	26.5%

The information listed in Table D-2 excludes any synchronous motors owned by the transmission customers. Synchronous machines were modeled explicitly in PSS/E.

Note that the dynamic model for the transmission customers simulates the response of both large and small motors, while the dynamic model for the distribution customers only simulates the response of small motors. This modeling methodology assumes that the vast majority of the motors served by the distribution system are small motors like those used for air conditioning and refrigeration.

D-SMES Model

The Power Technology, Inc. CSMES/TSMES model was used to represent the D-SMES units in the dynamic simulations. This model simulates both the real power and reactive power contributions of the D-SMES units.

Simulation Results

Load flow and dynamic system models, simulating summer peak conditions, were built for each study year between 2000 and 2005. The system was tested, in each study year, by the application of a three-phase fault to the Black Brook--Aurora St. 115 kV transmission line segment. Due to the breaker configuration at Black Brook, a fault on the Black Brook--Aurora St. line will also trip the Weston--Black Brook line segment.

Note: The addition of a breaker at Black Brook to sectionalize the Weston—Black Brook line segment does little to solve the voltage stability problems in the region due to the fact that an outage to the Black Brook—Aurora St. segment alone still presents significant concerns.

The voltage response of the Upper West transmission system to the fault and subsequent lockout of the Weston--Black Brook--Aurora St. line must meet the following criteria to be considered adequate:

- All 115 kV bus voltages must recover to levels exceeding 90% of nominal in less than one second.

  The D-SMES units have a 250% over-current capability for the first second of operation. When this capability is exhausted and the output of each D-SMES device is clamped at 100% of nominal, a dip in the system voltage will occur. If the system has not recovered to levels exceeding 90% of nominal by that time, a relapse into a voltage instability/collapse condition could occur due to this dip.
- All steady state 115 kV bus voltages must recover to levels exceeding 92% of nominal.

  The Upper West 115 kV bus voltages generally will operate at levels between 101% and 105% of nominal when the system is intact. If transmission system voltages fall below 92% for a steady state condition, the feeder voltage regulators (maximum boost of 10%) will not be able to hold distribution customer voltages at adequate levels.

Figures D-8, D-9 and D-10 are one-line diagrams of the intact Upper West transmission system for the 2001, 2002 and 2003 summers respectively.

Figure D-11 depicts the voltage response of the transmission system for each summer model when a permanent fault on the Black Brook--Aurora St. 115 kV line is initiated. The upper graph is the Aurora St. 115 kV bus voltage and the lower graph is the St. Germain 115 kV bus voltage. Note that in 2003, the 250% over-current rating of the D-SMES is exhausted before transmission system voltages recover to 80% of nominal. At that point the system is vulnerable to a voltage instability or voltage collapse condition based on the fact that end-of-line distribution system voltages may be lower than 80% of nominal. The D-SMES units are also at their steady state reactive limit with transmission system voltages at or near 90% of nominal. Figures D-12 through D-16 plot the response of each D-SMES unit for the 2003 summer Black Brook--Aurora St. fault. Based on these simulation results, it is clear that WPSC must address the voltage stability problem prior to the 2003 summer peak load period.

Factors to Consider when Developing a Present Value Revenue Requirement for the Upper West Reinforcement Alternatives

Upper West Single Contingency Criteria

WPSC Plans for transmission system reinforcements based upon a single contingency criterion. The criteria requires that, during peak demand periods, a forced outage to any single transmission system component will not cause any other facilities to overload or cause system voltages to fall below acceptable levels. Overloaded transmission system facilities may experience fatigue or failure due to excessive heat, while unacceptable voltages may cause an interruption of service or damage to customer equipment.

The analysis identified thermal (overload) limitations and the timing of reinforcements necessary to correct those limitations by the linear interpolation of load flow results taken from a low load base case (Upper West Load = 245 MW) and high load base case (Upper West Load = 272 MW). That linear interpolation identified Upper West load levels critical to any limitations. The critical Upper West load levels were then compared to the most recent growth projections for the area to identify the projected year in which the facilities would overload. Construction involved with the correction of the thermal limitation would take place in the year prior to the projected overload year.

The analysis also evaluated the voltage stability performance of each reinforcement alternative. The voltage stability study examined the Power Delivered vs. Voltage (P-V) characteristics of the Upper West system following a system disturbance. In an attempt to simulate the fast dynamic voltage response of the transmission system (the time period lasting several seconds after a disturbance), the load flow runs used to develop the P-V curves locked all load tap changing transformers (LTCs), voltage regulators and shunt capacitors. In addition, the loads in the region were modeled with voltage dependant characteristics. The loads for each customer class were broken down in the following manner:

Distribution customers (assumed to be mostly commercial/residential):
65% constant power
17.5% constant current
17.5% constant admittance
Directly Served customers (entirely industrial):
80% constant power
10% constant current
10% constant admittance

The voltage stability performance of each reinforcement alternative was considered adequate if:

- Projected Upper West area load was more than 10 MW below the system collapse point for a critical contingency.
  The 10 MW "stability margin" takes into account forecasting error and the possibility of a large customer addition in the area.
- the step voltage drop following a contingency is less than 0.10 per unit (p.u.), or 10% of the nominal voltage, at any transmission system bus.
  This number is based upon the fact that the WPSC distribution system attempts to control service voltages at levels above 0.95 p.u. If the distribution system experiences a voltage step change of greater than 0.10 p.u, end-of-line distribution service voltages will fall to levels of lower than 0.85 p.u. These low service voltages may raise the reactive power requirements of the system and lower voltages further, creating a voltage collapse condition.

In addition to single transmission line outages, the study evaluated an outage to the Weston #3 generating unit. Weston #3 provides critical support to the Wausau/Upper West transmission system through the production of real and reactive power.

A successful reinforcement plan for the Upper West must meet the single contingency criteria through at least the 2010 summer.

Wausau 46 kV Conversion

WPSC has plans to convert the northern 46 kV system in the Wausau area by 2007 due to expected load growth coupled with the age and condition of the 46 kV facilities. This conversion process has three distinct steps:

1.) Construct a Maine—Brokaw 115 kV line. This line would be energized initially at 46 kV and would replace Pine-Brokaw as the northern 46 kV source into Wausau. Scheduled for completion in 2001.

2.) Convert the Townline and Wausau Hydro substations to 115 kV and convert the existing Sherman St.-Wausau Hydro-Townline-Kelly 46 kV line to 115 kV operation. Reconfigure the remaining 46 kV system to accommodate the conversion. Scheduled for completion in 2003-2004.

3.) Convert the Strowbridge St. substation to 115 kV operation and loop it into the 115 kV system. The looping of Strowbridge St. has two options.
   a.) Construct a double circuit line from Wausau Hydro to Strowbridge St.
   b.) Construct a single circuit line from Wausau Hydro to Strowbridge St. to Brokaw.

   Scheduled for completion in 2005-2007.

Figure D-17 displays the steps in the 46 kV conversion process.

Upon completion of conversion step 3a, the Wausau area would require significant support from the Upper West transmission system during an outage to the line between the Sherman St. and Hilltop substations. Figure D-18 is a PSS/E one-line diagram of the load flow results for this contingency without an Upper West reinforcement in place. A large capacitor (153 MVAR) was needed in the Hilltop/Maine area to get the case to converge. Even with this capacitor in service, bus voltages in the Upper West were still below 90% of nominal. The flows through the Kelly-Bunker Hill and Weston—Black Brook 115 kV lines approached the emergency ratings of the phase conductors.

Clearly, step 3a is only feasible if a new line is built into the Upper West area to provide a new source separate from the Wausau system. Those Upper West reinforcement alternatives that only build upon the existing Upper West/Wausau transmission system would require the construction of step 3b, a Wausau Hydro-Strowbridge-Maine 115 kV line. Step 3b is estimated to cost $1,500,000 more than 3a ($3,350,000 vs. $1,850,000). Those Upper West reinforcement alternatives that require the construction of a Wausau Hydro-Strowbridge-Maine 115 kV line for the third step of the Wausau 46 kV conversion incurred a cost adder of $1,500,000 in the economic analysis.

345 kV Routing

Routing for the proposed Weston-Arrowhead 345 kV line is divided into two distinct corridors between Wausau and Ladysmith. The southern corridor heads straight west from Wausau until the routes join with an existing railroad/pipeline right-of-way and then heads in a northwesterly direction towards Ladysmith. The northern corridor heads north from Wausau towards the Tripoli area and then turns west heading to Ladysmith. Figure D-19 highlights the two 345 kV routing options in relation to the existing transmission facilities greater than 100 kV in central Wisconsin. On average, the northern corridor is longer than the southern corridor. The cost estimate for a reinforcement alternative that requires Weston--Arrowhead construction along the northern corridor will include costs associated with additional miles of 345 kV.

Transmission System Loss Benefits

The analysis calculated total system losses associated with each reinforcement alternative using a 2002 base case simulating summer peak load conditions with minimal interregional transfer levels. This model was used in an effort to capture the loss differentials associated with the load serving aspects of the reinforcements.

The reinforcement alternative with the highest loss total was assumed to have zero loss benefit. The other alternatives received a loss credit commensurate with their respective loss reductions relative to the highest loss alternative.

An economic loss benefit was calculated for each reinforcement alternative accounting for both capacity and energy savings. The present value analysis used the following parameters:

First Year of Loss Analysis:	2002	
Study Duration:	10 years	
Load Growth:	2%	
Load Factor:	70%	
Inflation Rate:	3%	
Rate of Capital:	10%	
Marginal Cost (Capacity)*:	$ 31.86/kW	
Marginal Cost (Energy)*:	2002	$ 18.08/MWh
	2003	$ 21.95/MWh
	2004	$ 20.49/MWh
	2005	$ 20.73/MWh
	2006	$ 23.04/MWh
	2007	$ 24.49/MWh
	2008	$ 24.42/MWh
	2009	$ 28.72/MWh
	2010	$ 31.43/MWh
	2011	$ 30.68/MWh

*Based on WPSC 1999-2000 Rate Case (PSCW Docket # 6690-UR-111).

Construction Costs

The present value analysis used the following values for the development of comparable construction costs for each alternative:

115 kV substation terminal addition/upgrade:	$ 225,000 / terminal
115 kV temporary line construction:	$ 33,000 / mile

These values, represented in 1999 dollars, are based upon generic unit construction costs developed by WPSC project estimators for the evaluation of reinforcement alternatives in Advance Plan 8.

Cost estimates for other system components have been specifically estimated by WPS for budgetary or other purposes. These figures are also represented in 1999 dollars.

345/115 kV substation with ring bus:	$ 4,000,000 / substation
Merrill—Tomahawk 46 kV conversion to 115 kV operation:	$ 4,222,000

The cost for 345 kV and 115 kV transmission line construction is based upon an average unit cost developed from specific estimates used in this CPCN application.

115 kV transmission line construction:	$ 227,000 / mile
345 kV transmission line construction:	$ 485,000 / mile

Upper West Transmission System Reinforcement Alternatives

1.) Tripoli – Highway 8 Plan

Description

This plan solves the Upper West voltage stability problem by installing a substation under the proposed 345 kV Weston—Arrowhead transmission line near the town of Tripoli and constructing a 115 kV transmission line between Tripoli and the Highway 8 substation located on the west side of Rhinelander. Construction of the proposed facilities would be complete by the end of 2002. Figure D-20 is a one-line diagram of the Tripoli—Highway 8 Plan.

Load Flow / Thermal Analysis

A study of the Tripoli—Highway 8 Plan did not reveal any thermal limitations through 2010.

Voltage Stability Analysis

Figure D-21 depicts the P-V curves for the critical line outage (Tripoli—Highway 8) and the Weston Unit #3 outage.

The system response to the most severe transmission system contingency, Tripoli—Highway 8, is adequate up to 285 MW. Based on the latest growth projections, Upper West load would not reach or exceed 285 MW until the 2015 summer.

The study results indicate that the system may exhibit voltage stability problems for an outage of Weston Unit #3 at an Upper West load level of 263 MW. That load level, combined with the Weston Unit #3 outage would cause transmission system bus voltages to rapidly drop 0.10 p.u, creating a potentially unstable situation. Based on the latest growth projections, Upper West load would not reach or exceed 263 MW until the 2011 summer.

Note that this voltage stability performance was attained without contributions from the six D-SMES units. Completion of the Tripoli—Highway 8 Plan would allow WPSC to remove and sell the D-SMES units. Therefore, this plan was credited $3,750,000 for the D-SMES removal and sale.

Wausau 46 kV Conversion

The Tripoli—Highway 8 Plan significantly strengthens the Upper West/Wausau 115 kV system with a new source. This added strength allows for the construction of Wausau 46 kV Conversion Step 3a (the Wausau—Strowbridge St.—Townline 115 kV loop). Since this is the lower cost alternative, this plan does not receive a cost adder associated with the Wausau 46 kV conversion.

345 kV Routing

This plan is the only Upper West reinforcement alternative that requires 345 kV construction along the northern corridor between Weston and Ladysmith. The northern route is the longer of the two corridors. This plan received an adder of $5,820,000 to represent the costs associated with the additional miles of 345 kV construction. This number represents the average cost differential between the route alternatives that follow the northern corridor and the southern corridor.

Transmission System Loss Benefits

The Tripoli—Highway 8 Plan reduces transmission system losses by 7.5 MW when compared to the highest loss plan (D-SMES Plan). The capacity and energy benefits associated with these loss savings were credited to this plan in the final economic analysis.

Construction Costs

Table D-3 summarizes the construction costs associated with the Tripoli—Highway 8 Plan.

Table D-3: Tripoli—Highway 8 Plan – Construction Costs.

Year	Reinforcement	Cost	Length (Mi.)	Voltage	Reinforcement Notes
2002	Construct Tripoli 345/115 kV substation	$ 4,000,000		345/115 kV	budget estimate
2002	Construct Tripoli--Highway 8 115 kV transmission line		42	115 kV	
	- 115 kV line cost	$ 9,534,000			
	- Highway 8 115 kV terminal	$ 225,000			
2002	Additional 345 kV line miles for Tripoli route vs. Owen route	$ 5,820,000	12	345 kV	
2002	Credit - removal and sale of six D-SMES units	$ (3,750,000)			units no longer necessary due to reinforcement

Present Value Calculation

Table D-4 displays the present value analysis conducted for the Tripoli—Highway 8 Plan. The Tripoli—Highway 8 Plan has a total present value of $12,094,404.

Table D-4: Present Value Calculation for the Tripoli—Highway 8 Plan.

Description: Tripoli--Highway 8 Plan

Analysis Year: 1999

Financial Assumptions

Inflation Rate:	3.0%
Rate of Capital:	10.0%

Load Assumptions

Load Growth:	2.0%
Load Factor:	70.0%

Loss Information

Loss Savings at the time of System Peak:	7.5	MW
First Year That Loss Benefits are Realized:	2002	
Study Duration:	10	Years

Construction Plans

Year	Project Description	1999 Construction Costs
2002	Tripoli 345/115 kV substation	$ 4,000,000
2002	Tripoli--Highway 8 115 kV transmission line	$ 9,534,000
2002	Highway 8 115 kV terminal	$ 225,000
2002	Additional 345 kV line miles	$ 5,820,000
2002	Credit for sale and removal of six D-SMES units	$ (3,750,000)

Present Value	1999 Dollars	
Construction Costs:	$	18,453,360
Loss Benefits (Energy):	$	(4,529,896)
Loss Benefits (Capacity):	$	(1,829,060)
Total Present Value Revenue Requirement:	$	12,094,404

2.) D-SMES Plan

Description

The D-SMES Plan corrects the Upper West voltage stability problem through the purchase of additional D-SMES units as Upper West load continues to grow. Based on current load projections, two new units should be added every three years. The cost to install one unit is $725,000. The D-SMES plan proposes to add units in the following years; 2003, 2004, 2006, 2007, 2009, 2010.

Load Flow/Thermal Analysis

Table D-5 summarizes the load flow results for the high and low load base cases and the associated interpolation that identifies thermal limits.

Table D-5: D-SMES Plan – Thermal Limitations.

	Existing Limitations							
Upper West Plan	Overloaded Segment	Outage	LOW Loading (%)	HIGH Loading (%)	Limiting Element(s)	Rating (MVA)	Critical UW Load (MW)	Overload Year
D-SMES Plan	Bunker Hill--Black Brook	Weston--Black Brook	101.3	119.1	CONDUCTOR	92	243	2007
	Venus--Summit Lake	Eastom--Highway 8	97.0	115	ct	169	250	2008
	Summit Lake--Aurora St.	Eastom--Highway 8	100.9	118.6	ct	169	244	2007
	Eastom--Highway 8	Aurora St.--Black Brook	105.5	126.9	disc, bkr, ct	159	238	2006
	New Limitations							
	Overloaded Segment	Outage	LOW Loading (%)	HIGH Loading (%)	Limiting Element(s)	Rating (MVA)	Critical UW Load (MW)	Overload Year
	Bunker Hill--Black Brook	Weston--Black Brook	38.7	45.5	REBUILT LINE	241	488	9999
	Venus--Summit Lake	Eastom--Highway 8	90.6	107.4	CONDUCTOR	181	260	2010
	Summit Lake--Aurora St.	Eastom--Highway 8	94.2	110.7	CONDUCTOR	181	254	2009
	Eastom--Highway 8	Aurora St.--Black Brook	96.4	116.0	CONDUCTOR	174	250	2008

The study of potential thermal limitations identified the need for the following reinforcements:

- Rebuild Bunker Hill—Black Brook 115 kV (2006).
- Rebuild Eastom—Highway 8 115 kV (2007)*.
- Rebuild Summit Lake—Aurora St. 115 kV (2008)*.
- Rebuild Venus—Summit Lake 115 kV (2009)*

* Reconstruction of the highlighted facilities would require the installation of a temporary line to maintain looped service to the Upper West area during the construction period.

Figure D-22 depicts the proposed D-SMES Plan that includes the transmission line reinforcements necessary to meet the thermal requirements of the single contingency criteria.

Voltage Stability Analysis

The additional D-SMES units proposed as a part of this plan will provide adequate voltage support through 2010.

Wausau 46 kV Conversion

Since the D-SMES Plan does not add a new source to the Upper West/Wausau transmission system, it will require the construction of Wausau 46 kV Conversion Step 3b (the Wausau—Strowbridge St.—Maine 115 kV). A cost adder of $1,500,000 was included in the present value analysis to account for the cost differential between the two Wausau 46 kV conversion plans.

345 kV Routing

This plan would allow for 345 kV construction along the southern corridor between Weston and Ladysmith. No cost adder is necessary for the present value analysis.

Transmission System Loss Benefits

The D-SMES Plan has the highest transmission system losses of any alternative. The present value analysis does not contain any transmission system loss benefits.

Construction Costs

Table D-6 summarizes the construction costs associated with the D-SMES Plan.

Table D-6: D-SMES Plan – Construction Costs.

Year	Reinforcement	Cost	Length (Mi.)	Voltage	Reinforcement Notes
2003	Add one D-SMES Unit	$ 725,000		24.9 kV	
2004	Add one D-SMES Unit	$ 725,000		24.9 kV	
2005	Cost Adder - Wausau 46 kV conversion	$ 1,500,000		115 kV	Wausau 46 kV conversion plan 3b required
2006	Upgrade Eastom--Highway 8 terminals	$ 225,000		115 kV	
2006	Add one D-SMES Unit	$ 725,000		24.9 kV	
2006	Rebuild Bunker Hill--Black Brook	$ 1,816,000	8	115 kV	
2007	Add one D-SMES Unit	$ 725,000		24.9 kV	
2007	Rebuild Eastom--Highway 8		21	115 kV	
	- 115 kV line cost	$ 4,767,000			
	- Temporary line cost	$ 693,000			necessary to maintain looped service during rebuild
2008	Rebuild Summit Lake--Aurora St.		16	115 kV	
	- 115 kV line cost	$ 3,632,000			
	- Temporary line cost	$ 528,000			necessary to maintain looped service during rebuild
2009	Add one D-SMES Unit	$ 725,000		24.9 kV	
2009	Rebuild Venus--Summit Lake		14	115 kV	
	- 115 kV line cost	$ 3,178,000			
	- Temporary line cost	$ 462,000			necessary to maintain looped service during rebuild
2010	Add one D-SMES Unit	$ 725,000		24.9 kV	

Present Value Calculation

Table D-7 displays the present value analysis conducted for D-SMES Plan. The D-SMES Plan has a total present value of $17,616,987.

Table D-7: Present Value Calculation for the D-SMES Plan.

Description: D-SMES Plan

Analysis Year: 1999

Financial Assumptions

Inflation Rate:	3.0%
Rate of Capital:	10.0%

Load Assumptions

Load Growth:	2.0%
Load Factor:	70.0%

Loss Information

Loss Savings at the time of System Peak:	0	MW
First Year That Loss Benefits are Realized:	2002	
Study Duration:	10	Years

Construction Plans

Year	Project Description	1999 Construction Costs
2003	Add one D-SMES unit	$ 725,000
2004	Add one D-SMES unit	$ 725,000
2005	Cost Adder - Wausau 46 kV conversion	$ 1,500,000
2006	Upgrade Eastom--Highway terminals	$ 225,000
2006	Add one D-SMES unit	$ 725,000
2006	Rebuild Bunker Hill--Black Brook 115 kV	$ 1,816,000
2007	Add one D-SMES unit	$ 725,000
2007	Rebuild Eastom--Highway 8 115 kV	$ 4,767,000
2007	Eastom--Highway 8 temporary line	$ 693,000
2008	Rebuild Summit Lake--Aurora St. 115 kV	$ 3,632,000
2008	Summit Lake--Aurora St. temporary line	$ 528,000
2009	Add one D-SMES unit	$ 725,000
2009	Rebuild Venus--Summit Lake 115 kV	$ 3,178,000
2009	Venus--Summit Lake temporary line	$ 462,000
2010	Add one D-SMES unit	$ 725,000

Present Value	1999 Dollars	
Construction:	$	17,616,987
Loss Benefits (Energy):	$	-
Loss Benefits (Capacity):	$	-
Total Present Value Revenue Requirement:	$	17,616,987

3.) Parallel Circuit Plan

Description

The Parallel Circuit Plan corrects the Upper West voltage stability problem by replacing critical line segments utilizing single circuit H-frame structures with parallel 115 kV lines comprised of single pole structures. The existing 115 kV transmission line between Black Brook switching station and Aurora St. substation would be replaced with parallel 115 kV circuits in a manner that minimizes new right-of-way acquisition. Black Brook switching station would be eliminated, and the transmission system reconfigured to create a Weston—Aurora St. line and a Bunker Hill—Aurora St. line. The existing 115 kV transmission line between Skanawan switching station and Highway 8 substation would be replaced with parallel 115 kV circuits in a manner that minimizes new right-of-way acquisition. This plan would also convert the 46 kV system between Merrill and Tomahawk to 115 kV operation. Skanawan switching station would be eliminated, and the transmission system reconfigured to create a Pine—Highway 8 line and an Eastom—Highway 8 line. The reconfiguration would allow for the removal of an existing Eastom—Skanawan 115 kV line. Installation of the parallel circuits would require the use of temporary lines to maintain looped service to the Upper West area during the construction periods. Figure D-23 depicts the transmission system changes proposed in the Parallel Circuit Plan.

Load Flow / Thermal Analysis

A study of the Parallel Circuit Plan did not reveal any thermal limitations through 2010.

Voltage Stability Analysis

Figure D-24 depicts the P-V curves for the critical line outage (Maine--Pine) and the Weston Unit #3 outage.

The system response to the most severe transmission system contingency, Maine--Pine, is adequate up to 267 MW. Based on the latest growth projections, Upper West load would not reach or exceed 267 MW until the 2012 summer. That performance level was attained without the original six D-SMES units in service. With the D-SMES units in service, a higher load limit would be expected.

The study results indicate that the system may exhibit voltage stability problems for an outage of Weston Unit #3 at an Upper West load level of 233 MW. That load level, combined with the Weston #3 outage would cause transmission system bus voltages to rapidly drop 0.10 p.u., creating a potentially unstable situation. Based on the latest growth projections, Upper West load would reach or exceed 233 MW by the 2005 summer. To adequately protect the transmission system through 2010, WPSC would keep the original six D-SMES units in service to support system voltages in the event of a Weston Unit #3 contingency.

Wausau 46 kV Conversion

Since the Parallel Circuit Plan does not add a new source to the Upper West/Wausau transmission system, it will require the construction of Wausau 46 kV Conversion Step 3b (the Wausau—Strowbridge St.—Maine 115 kV). A cost adder of $1,500,000 was included in the present value analysis to account for the cost differential between the two Wausau 46 kV conversion plans.

345 kV Routing

This plan would allow for 345 kV construction along the southern corridor between Weston and Ladysmith. No cost adder is necessary for the present value analysis.

Transmission System Loss Benefits

The Parallel Circuit Plan reduces transmission system losses by 2.5 MW when compared to the highest loss plan (D-SMES Plan). The capacity and energy benefits associated with these loss savings were credited to this plan in the final economic analysis.

Construction Costs

Table D-8 summarizes the construction costs associated with the Parallel Circuit Plan.

Table D-8: Parallel Circuit Plan – Construction Costs.

Year	Reinforcement	Cost	Length (Mi.)	Voltage	Reinforcement Notes
2001	Construct Black Brook--Aurora St. parallel 115 kV circuits		8	115 kV	
	- 115 kV line cost, two circuits	$ 3,632,000			
	- Aurora St. 115 kV terminal	$ 225,000			
	- Temporary line cost	$ 264,000			necessary to maintain looped service during rebuild
2001	Convert Merrill--Tomahawk 46 kV system to 115 kV	$ 4,222,000		115 kV	cost taken from CPCN application, inflated two years
2002	Construct Skanawan--Highway 8 parallel 115 kV circuits		16	115 kV	
	- 115 kV line cost, two circuits	$ 7,264,000			
	- Highway 8 115 kV terminal	$ 225,000			
	- Temporary line cost	$ 528,000			necessary to maintain looped service during rebuild
2005	Cost Adder - Wausau 46 kV conversion	$ 1,500,000		115 kV	Wausau 46 kV conversion plan 3b required

Present Value Calculation

Table D-9 displays the present value analysis conducted for Parallel Circuit Plan. The Parallel Circuit Plan has a total present value of $19,048,300.

Table D-9: Present Value Calculation for the Parallel Circuit Plan.

Description: Parallel Circuit Plan

Analysis Year: 1999

Financial Assumptions

Inflation Rate:	3.0%
Rate of Capital:	10.0%

Load Assumptions

Load Growth:	2.0%
Load Factor:	70.0%

Loss Information

Loss Savings at the time of System Peak:	2.5	MW
First Year That Loss Benefits are Realized:	2002	
Study Duration:	10	Years

Construction Plans

Year	Project Description	1999 Construction Costs
2001	Construct Black Brook--Aurora St. parallel 115 kV circuits	$ 3,632,000
2001	Aurora St. 115 kV terminal	$ 225,000
2001	Black Brook--Aurora St. termporary line	$ 264,000
2001	Convert Merrill--Tomahawk 46 kV system to 115 kV	$ 4,222,000
2002	Construct Skanawan--Highway 8 parallel 115 kV circuits	$ 7,264,000
2002	Highway 8 115 kV terminal	$ 225,000
2002	Skanawan--Highway 8 temporary line	$ 528,000
2005	Cost Adder - Wausau 46 kV conversion	$ 1,500,000

Present Value	1999 Dollars	
Construction:	$	21,169,045
Loss Benefits (Energy):	$	(1,510,747)
Loss Benefits (Capacity):	$	(609,998)
Total Present Value Revenue Requirement:	$	19,048,300

4.) Black Brook—Venus 345 kV Plan

Description

This plan solves the Upper West voltage stability problem by constructing a new 345 kV transmission line between Black Brook switching station and Venus substation. The new line would be energized initially at 115 kV. The Bunker Hill—Black Brook 115 kV line would be rebuilt and Black Brook switching station removed to create a Weston—Venus line and a Bunker Hill—Aurora St. line. Figure D-25 depicts the transmission system changes proposed as a part of the Black Brook—Venus 345 kV plan.

The proposal for 345 kV construction is based upon the inclusion of Black Brook--Venus in future plans to strengthen the Wisconsin—Upper Peninsula transmission system interface. The Advance Plan 8 Northeast Area Study (Technical Support Document D23p) identified the need to add a second 345 kV transmission line emanating from Michigan's Upper Peninsula following the eventual shut down of the Empire and Tilden mines. The new line would be necessary to maximize the use of available generating capacity at the Presque Isle Power Plant, located near Marquette, MI. One alternative to provide the generation outlet is a Presque Isle—Plains (Iron Mountain, MI)—Venus—Black Brook—Weston 345 kV line. All but six miles of the transmission line between Weston and Black Brook is built for 345 kV operation.

Load Flow / Thermal Analysis

A study of the Black Brook—Venus 345 kV Plan did not reveal any thermal limitations through 2010.

Voltage Stability Analysis

Figure D-26 depicts the P-V curves for the critical line outage (Weston--Venus) and the Weston Unit #3 outage.

The system response to the most severe transmission system contingency, Weston--Venus, is adequate up to 268 MW. Based on the latest growth projections, Upper West load would not reach or exceed 268 MW until the 2012 summer. That performance level was attained without the original six D-SMES units in service. With the D-SMES units in service, a higher load limit would be expected.

The study results indicate that the system may exhibit voltage stability problems for an outage of Weston Unit #3 at an Upper West load level of 239 MW. That load level, combined with the Weston #3 outage would cause transmission system bus voltages to rapidly drop 0.10 p.u, creating a potentially unstable situation. Based on the latest growth projections, Upper West load would reach or exceed 239 MW by the 2006 summer. To adequately protect the transmission system through 2010, WPSC would keep the original six D-SMES units in service to support system voltages in the event of a Weston Unit #3 contingency.

Wausau 46 kV Conversion

Since the Black Brook—Venus 345 kV Plan does not add a new source to the Upper West/Wausau transmission system, it will require the construction of Wausau 46 kV Conversion Step 3b (the Wausau—Strowbridge St.—Maine 115 kV). A cost adder of $1,500,000 was included in the present value analysis to account for the cost differential between the two Wausau 46 kV conversion plans.

345 kV Routing

This plan would allow for 345 kV construction along the southern corridor between Weston and Ladysmith. No cost adder is necessary for the present value analysis.

Transmission System Loss Benefits

The Black Brook—Venus 345 kV Plan reduces transmission system losses by 2.8 MW when compared to the highest loss plan (D-SMES Plan). The capacity and energy benefits associated with these loss savings were credited to this plan in the final economic analysis.

Construction Costs

Table D-10 summarizes the construction costs associated with the Black Brook—Venus 345 kV Plan.

Table D-10: Black Brook—Venus 345 kV Plan – Construction Costs.

Year	Reinforcement	Cost	Length (Mi.)	Voltage	Reinforcement Notes
2002	Construct Black Brook--Venus 345 kV transmission line		40	345 kV	
	- 345 kV line cost	$ 19,400,000			
	- Venus 115 kV terminal	$ 225,000			
2002	Rebuild Bunker Hill-Black Brook	$ 1,816,000	8	115 kV	
2005	Cost Adder - Wausau 46 kV conversion	$ 1,500,000		115 kV	Wausau 46 kV conversion plan 3b required

Present Value Calculation

Table D-11 displays the present value analysis conducted for Black Brook—Venus 345 kV Plan. The Black Brook—Venus 345 kV Plan has a total present value of $24,057,734.

Table D-11: Present Value Calculation for the Black Brook—Venus 345 kV Plan.

Description: Black Brook--Venus 345 kV Plan
Analysis Year: 1999

Financial Assumptions

Inflation Rate:	3.0%
Rate of Capital:	10.0%

Load Assumptions

Load Growth:	2.0%
Load Factor:	70.0%

Loss Information

Loss Savings at the time of System Peak:	2.8 MW
First Year That Loss Benefits are Realized:	2002
Study Duration:	10 Years

Construction Plans

Year	Project Description	1999 Construction Costs
2002	Construct Black Brook--Venus 345 kV line	$ 19,400,000
2002	Venus 115 kV terminal	$ 225,000
2002	Rebuild Bunker Hill--Black Brook 115 kV line	$ 1,816,000
2005	Cost Adder - Wausau 46 kV conversion	$ 1,500,000

Present Value 1999 Dollars		
Construction Costs:	$	26,431,442
Loss Benefits (Energy):	$	(1,690,963)
Loss Benefits (Capacity):	$	(682,745)
Total Present Value Revenue Requirement:	$	24,057,734

5.) Black Brook—Venus 115 kV Plan

Description

This plan solves the Upper West voltage stability problem by constructing a new 115 kV transmission line between Black Brook switching station and Venus substation. The Bunker Hill—Black Brook 115 kV line would be rebuilt and Black Brook switching station expanded to sectionalize the Weston--Black Brook--Venus line and the Bunker Hill--Black Brook--Aurora St. line. Figure D-27 depicts the transmission system changes proposed as a part of the Black Brook—Venus 115 kV plan.

Load Flow / Thermal Analysis

A study of the Black Brook—Venus 115 kV Plan did not reveal any thermal limitations through 2010.

Voltage Stability Analysis

Figure D-28 depicts the P-V curves for the critical line outage (Weston—Black Brook) and the Weston Unit #3 outage.

The system response to the most severe transmission system contingency, Weston—Black Brook, is adequate up to 278 MW. Based on the latest growth projections, Upper West load would not reach or exceed 278 MW until the 2014 summer. That performance level was attained without the original six D-SMES units in service. With the D-SMES units in service, a higher load limit would be expected.

The study results indicate that the system may exhibit voltage stability problems for an outage of Weston Unit #3 at an Upper West load level of 237 MW. That load level, combined with the Weston #3 outage would cause transmission system bus voltages to rapidly drop 0.10 p.u, creating a potentially unstable situation. Based on the latest growth projections, Upper West load would reach or exceed 237 MW by the 2006 summer. To adequately protect the transmission system through 2010, WPSC would keep the original six D-SMES units in service to support system voltages in the event of a Weston Unit #3 contingency.

Wausau 46 kV Conversion

Since the Black Brook—Venus 115 kV Plan does not add a new source to the Upper West/Wausau transmission system, it will require the construction of Wausau 46 kV Conversion Step 3b (the Wausau—Strowbridge St.—Maine 115 kV). A cost adder of $1,500,000 was included in the present value analysis to account for the cost differential between the two Wausau 46 kV conversion plans.

345 kV Routing

This plan would allow for 345 kV construction along the southern corridor between Weston and Ladysmith. No cost adder is necessary for the present value analysis.

Transmission System Loss Benefits

The Black Brook—Venus 115 kV Plan reduces transmission system losses by 2.2 MW when compared to the highest loss plan (D-SMES Plan). The capacity and energy benefits associated with these loss savings were credited to this plan in the final economic analysis.

Construction Costs

Table D-12 summarizes the construction costs associated with the Black Brook—Venus 115 kV Plan.

Table D-12: Black Brook—Venus 115 kV Plan – Construction Costs.

Year	Reinforcement	Cost	Length (Mi.)	Voltage	Reinforcement Notes
2002	Construct Black Brook--Venus 115 kV transmission line		40	115 kV	
	- 115 kV line cost	$ 9,080,000			
	- Venus 115 kV terminal	$ 225,000			
	- Expand Black Brook Switching station	$ 675,000			
2002	Rebuild Bunker Hill-Black Brook	$ 1,816,000	8	115 kV	
2005	Cost Adder - Wausau 46 kV conversion	$ 1,500,000		115 kV	Wausau 46 kV conversion plan 3b required

Present Value Calculation

Table D-13 displays the present value analysis conducted for Black Brook—Venus 115 kV Plan. The Black Brook—Venus 115 kV Plan has a present value revenue requirement of $13,322,855.

Table D-13: Present Value Calculation for the Black Brook—Venus 115 kV Plan.

Description: Black Brook--Venus 115 kV Plan
Analysis Year: 1999

Financial Assumptions

Inflation Rate:	3.0%
Rate of Capital:	10.0%

Load Assumptions

Load Growth:	2.0%
Load Factor:	70.0%

Loss Information

Loss Savings at the time of System Peak:	2.2 MW
First Year That Loss Benefits are Realized:	2002
Study Duration:	10 Years

Construction Plans

Year	Project Description	1999 Construction Costs
2002	Construct Black Brook--Venus 115 kV line	$ 9,080,000
2002	Expand Black Brookswitching station	$ 675,000
2002	Add Venus 115 kV terminal	$ 225,000
2002	Rebuild Bunker Hill--Black Brook 115 kV line	$ 1,816,000
2005	Cost Adder - Wausau 46 kV conversion	$ 1,500,000

Present Value	1999 Dollars	
Construction:	$	15,187,355
Loss Benefits (Energy):	$	(1,328,185)
Loss Benefits (Capacity):	$	(536,315)
Total Present Value Revenue Requirement:	$	13,322,855

6.) Prentice—Highway 8 Plan

Description

This plan solves the Upper West voltage stability problem by reinforcing the Northern States Power/Dairyland Power Cooperative (NSP/DPC) 115 kV transmission system in central Wisconsin and linking it to the Upper West area. The construction of a 345/115 kV substation under the proposed 345 kV Weston—Arrowhead transmission line near the city of Ladysmith combined with a 115 kV transmission line between the new Ladysmith substation and NSP's existing Osprey substation would reinforce the NSP/DPC central Wisconsin system. The NSP/DPC system would then be tied to the Upper West by the construction of a Prentice--Highway 8 115 kV line. Construction of the proposed facilities would be complete by the end of 2002. Figure D-29 is a one-line diagram of the Prentice—Highway 8 Plan.

Load Flow / Thermal Analysis

A study of the Prentice—Highway 8 Plan did not reveal any thermal limitations through 2010.

Voltage Stability Analysis

Figure D-30 depicts the P-V curves for the critical line outage (Black Brook—Aurora St.) and the Weston Unit #3 outage.

The system response to the most severe transmission system contingency, Black Brook—Aurora St., is adequate up to 272 MW. Based on the latest growth projections, Upper West load would not reach or exceed 272 MW until the 2012 summer.

The study results indicate that the system may exhibit voltage stability problems for an outage of Weston Unit #3 at an Upper West load level of 253 MW. That load level, combined with the Weston Unit #3 outage would cause transmission system bus voltages to rapidly drop 0.10 p.u, creating a potentially unstable situation. Based on the latest growth projections, Upper West load would not reach or exceed 253 MW until the 2009 summer.

Note that this voltage stability performance was attained without contributions from the six D-SMES units. Completion of the Prentice—Highway 8 Plan would allow WPSC to remove and sell the D-SMES units. Therefore, this plan was credited $3,750,000 for the D-SMES removal and sale.

Wausau 46 kV Conversion

The Prentice—Highway 8 Plan significantly strengthens the Upper West/Wausau 115 kV system with a new source. This added strength allows for the construction of Wausau 46 kV Conversion Step 3a (the Wausau—Strowbridge St.—Townline 115 kV loop). Since this is the lower cost alternative, this plan does not receive a cost adder associated with the Wausau 46 kV conversion.

345 kV Routing

This plan would allow for 345 kV construction along the southern corridor between Weston and Ladysmith. No cost adder is necessary for the present value analysis.

Transmission System Loss Benefits

The Prentice—Highway 8 Plan reduces transmission system losses by 0.1 MW when compared to the highest loss plan (D-SMES Plan). The capacity and energy benefits associated with these loss savings were credited to this plan in the final economic analysis.

Construction Costs

Table D-14 summarizes the construction costs associated with the Prentice—Highway 8 Plan.

Table D-14: Prentice—Highway 8 Plan – Construction Costs.

Year	Reinforcement	Cost	Length (Mi.)	Voltage	Reinforcement Notes
2002	Construct Ladysmith 345/115 kV substation	$ 4,000,000		345/115 kV	assumed to be same design as Tripoli
2002	Construct Ladysmith--Osprey/Big Falls 115 kV line		12	115 kV	
	- 115 kV line cost	$ 2,724,000			
	- Osprey/Big Falls 115 kV terminal	$ 225,000			
2002	Constuct Prentice--Highway 8 115 kV line		64	115 kV	
	- 115 kV line cost	$ 14,280,000			
	- Highway 8 115 kV terminal	$ 225,000			
	- Prentice 115 kV terminal	$ 225,000			
2002	Credit - removal and sale of six D-SMES units	$ (3,750,000)			units no longer necessary due to reinforcement

Present Value Calculation

Table D-15 displays the present value analysis conducted for the Prentice—Highway 8 Plan. The Prentice—Highway 8 Plan has a present value revenue requirement of $20,817,028.

Table D-15: Present Value Calculation for the Prentice—Highway 8 Plan.

Description: Prentice--Highway 8 Plan
Analysis Year: 1999

Financial Assumptions

Inflation Rate:	3.0%
Rate of Capital:	10.0%

Load Assumptions

Load Growth:	2.0%
Load Factor:	70.0%

Loss Information

Loss Savings at the time of System Peak:	0.1	MW
First Year That Loss Benefits are Realized:	2002	
Study Duration:	10	Years

Construction Plans

Year	Project Description	1999 Construction Costs	
2002	Construct Ladysmith 345/115 kV substation	$	4,000,000
2002	Construct Ladysmith--Osprey/Big Falls 115 kV line	$	2,724,000
2002	Osprey/Big Falls 115 kV terminal	$	225,000
2002	Construct Prentice--Highway 8 115 kV line	$	14,280,000
2002	Highway 8 115 kV terminal	$	225,000
2002	Prentice 115 kV terminal	$	225,000
2002	Credit for sale and removal of six D-SMES units	$	(3,750,000)

Present Value	1999 Dollars	
Construction:	$	20,901,529
Loss Benefits (Energy):	$	(60,193)
Loss Benefits (Capacity):	$	(24,308)
Total Present Value Revenue Requirement:	$	20,817,028

Upper West Generation Reinforcement Alternative

The installation and operation of a small gas turbine generator could provide voltage support for the Upper West transmission system. A generator with a capacity of 40 MW would adequately protect the system through the 2010 summer. The installation of a 40 MW generator would cost approximately $16,000,000 ($400/kW).

When evaluating this alternative it is important to realize that the generator must be on-line when a critical transmission system contingency occurs. Small gas turbines, due to their high operating cost, can economically operate for only 100-200 hours per year. To ensure that the generator is operating when the system is at risk of voltage collapse, the unit would be given a "must-run" designation. This "must-run" designation would require the operation of the unit when Upper West loads reach or exceed a critical level (approximately 220 MW), even if it is not economical to do so.

The infrequent operation of gas turbines also impacts other factors used to evaluate the reinforcement alternatives.

- Transmission system loss savings would be negligible due to the fact that the generator would only operate for a fraction of the hours in a year.
- The Wausau 46 kV conversion plans would be affected as well. Conversion Step 3a (Strowbridge loop) would require support from the generator during the Sherman St.—Hilltop contingency. Due to the severe nature of this contingency, support would be needed for the majority of the hours in a year. Rather than assign a "must-run" designation for this contingency, Conversion Step 3b (Wausau—Strowbridge—Maine) would be completed.
- The D-SMES units would remain in service to support the Upper West transmission system during contingencies that occur when the generator is off-line.

Table D-16 displays the present value calculation conducted for the generation reinforcement alternative. The generation alternative has present value revenue requirement of $20,088,354.

Table D-16: Present Value Calculation for the Generation Alternative.

Description: Generation Alternative

Analysis Year: 1999

Financial Assumptions

Inflation Rate:	3.0%
Rate of Capital:	10.0%

Load Assumptions

Load Growth:	2.0%
Load Factor:	70.0%

Loss Information

Loss Savings at the time of System Peak:	0	MW
First Year That Loss Benefits are Realized:	2002	
Study Duration:	10	Years

Construction Plans

Year	Project Description	1999 Construction Costs
2002	Install 40 MW Gas Turbine	$ 16,000,000
2005	Cost Adder - Wausau 46 kV conversion	$ 1,500,000

Present Value	1999 Dollars	
Construction:	$	20,088,354
Loss Benefits (Energy):	$	-
Loss Benefits (Capacity):	$	-
Total Present Revenue Requirement:	$	20,088,354

Figure D-1: Upper West Area.

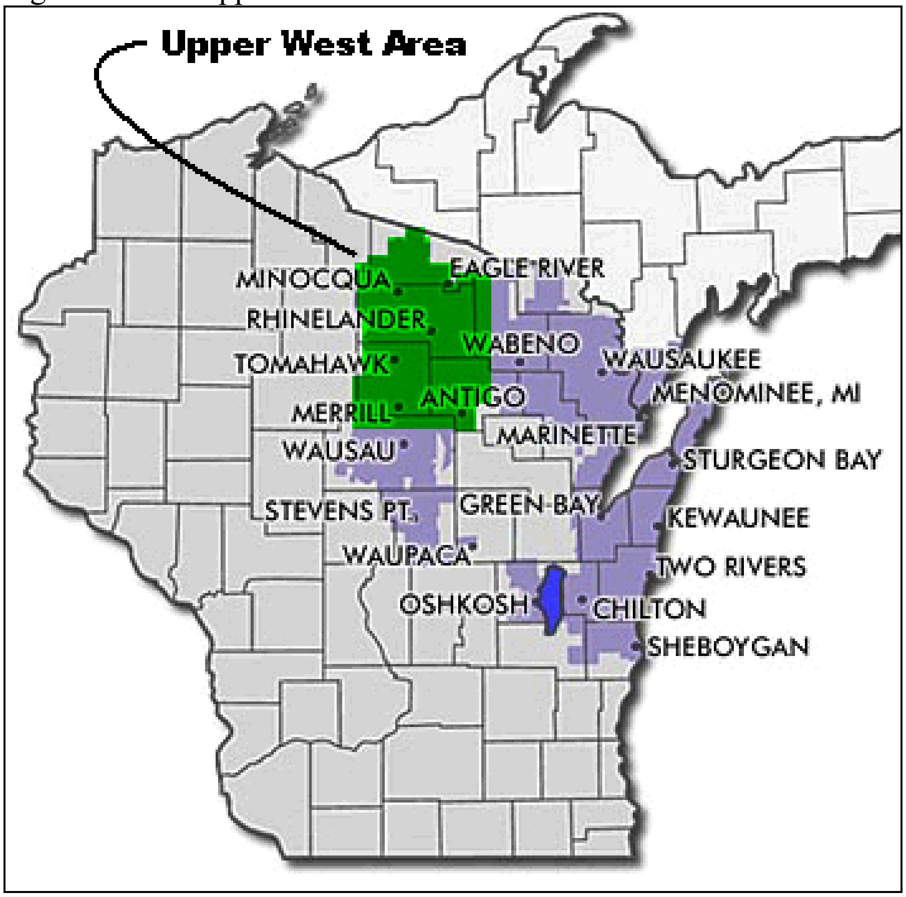


Figure D-2: Wausau/Upper West Transmission System

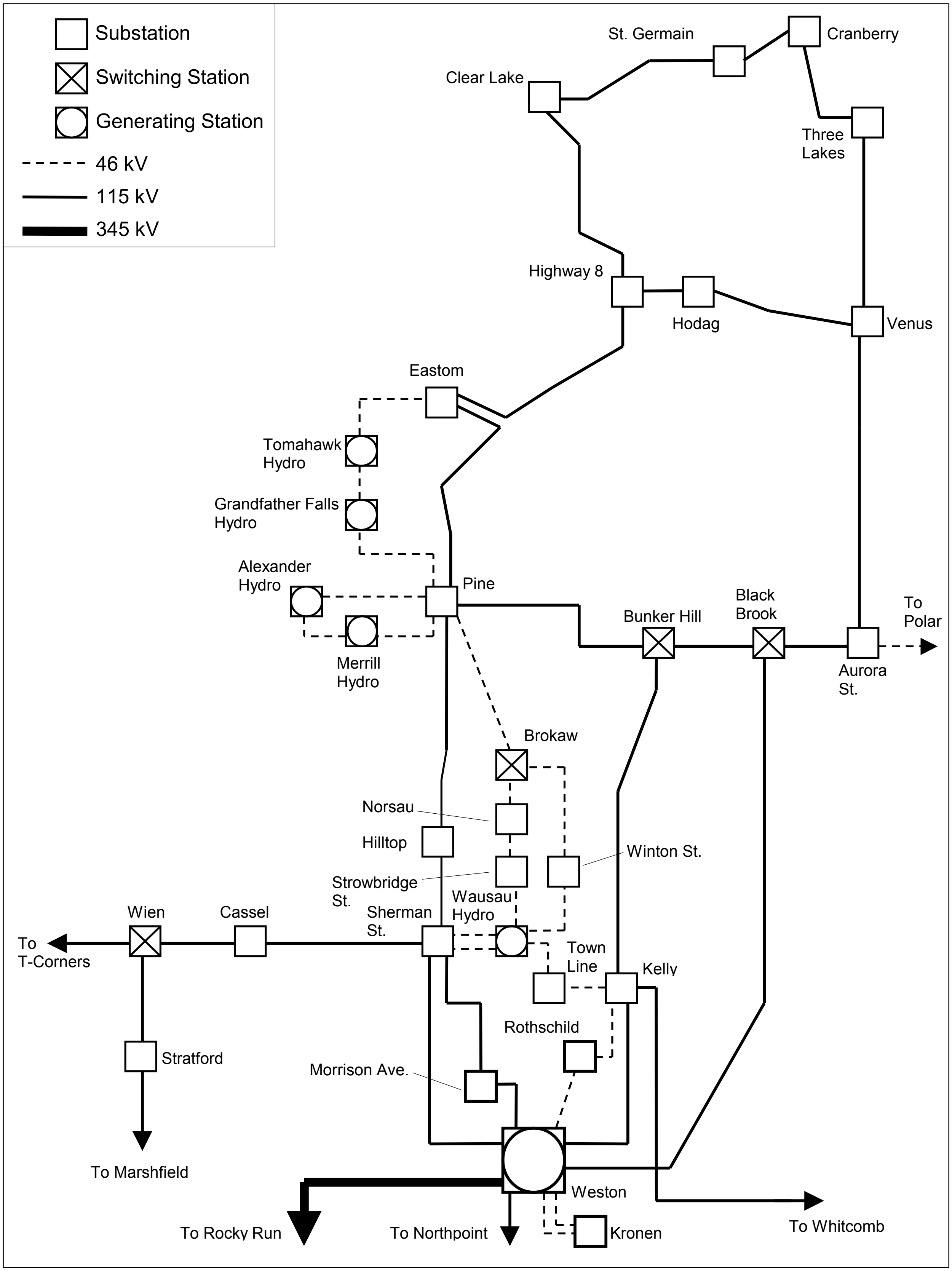


Figure D-3: Wausau/Upper West Transmission System – Near-Term Projects.

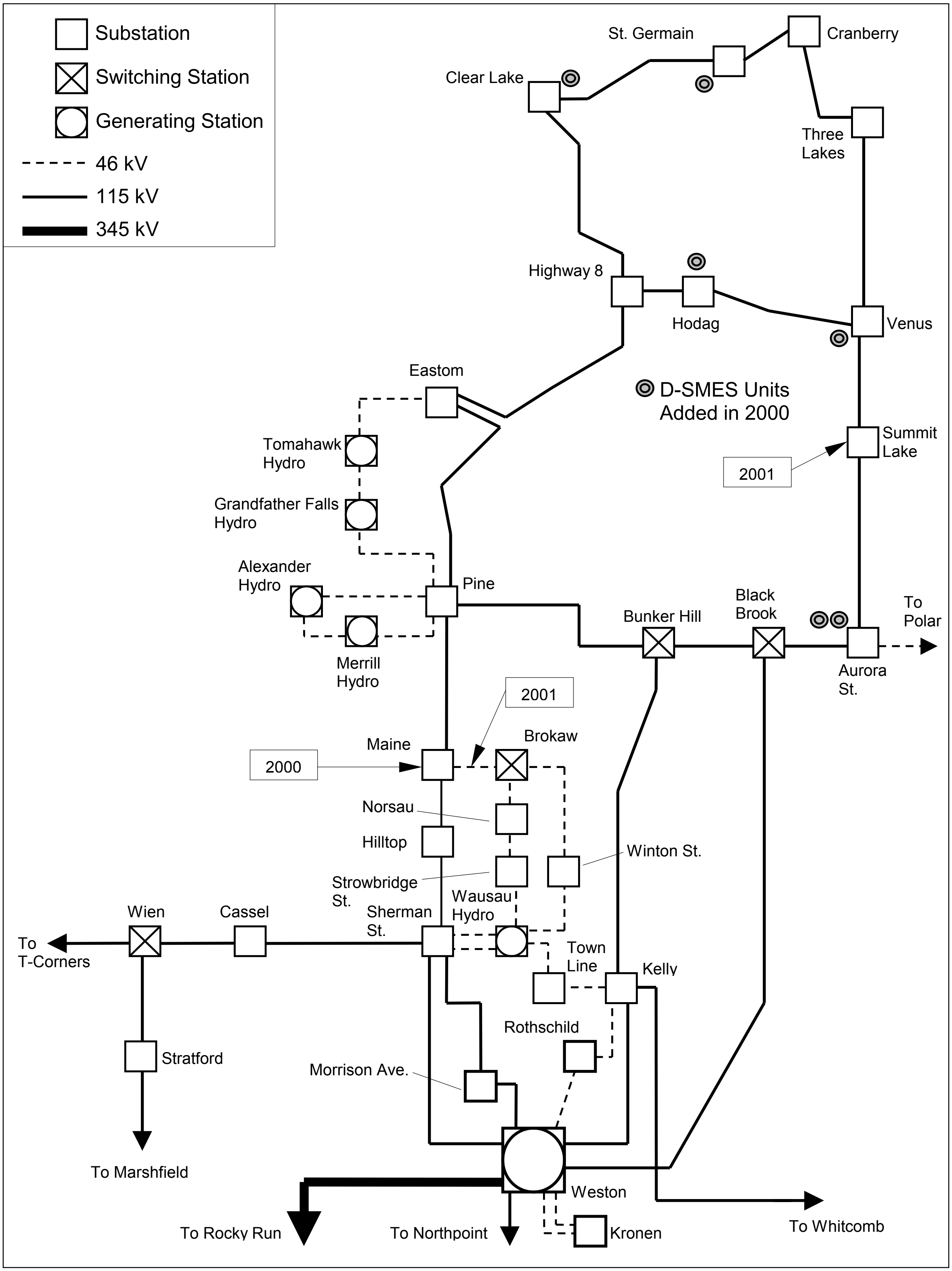


Figure D-4:	Upper West Historical Loads.

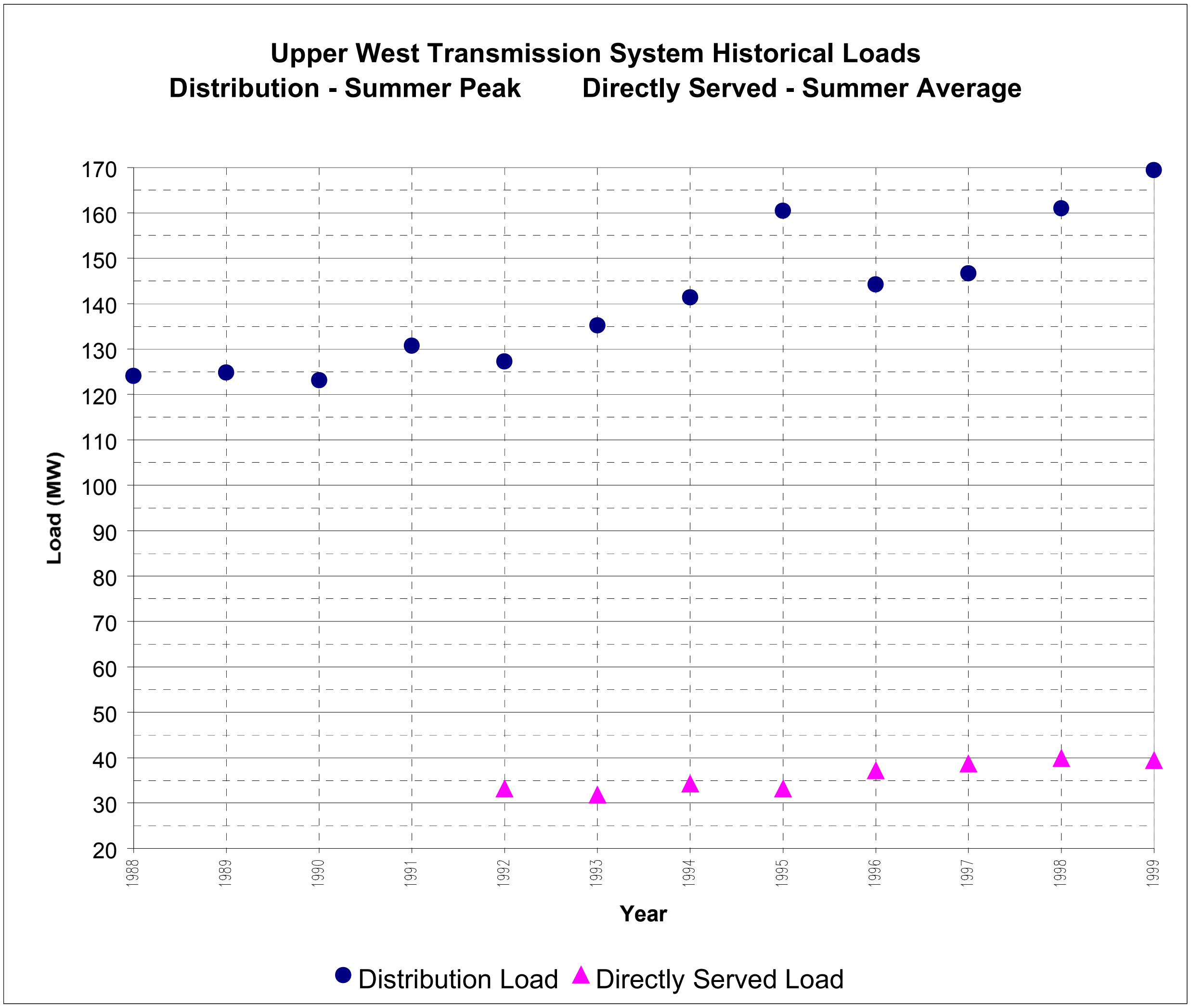


Figure D-5: Upper West Summer Peak Load Projection.

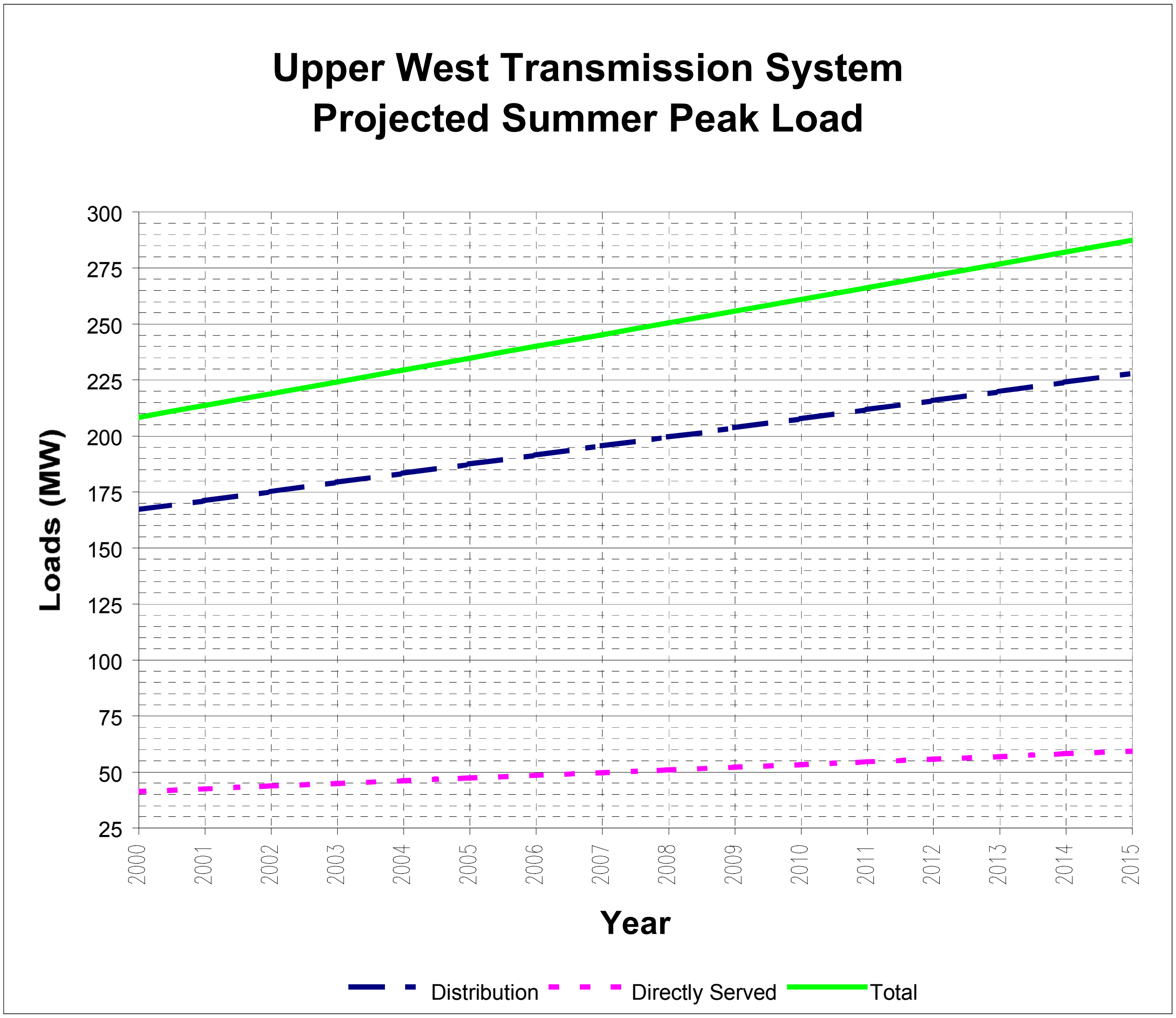


Figure D-6: Critical Upper West Transmission Line Contingencies.

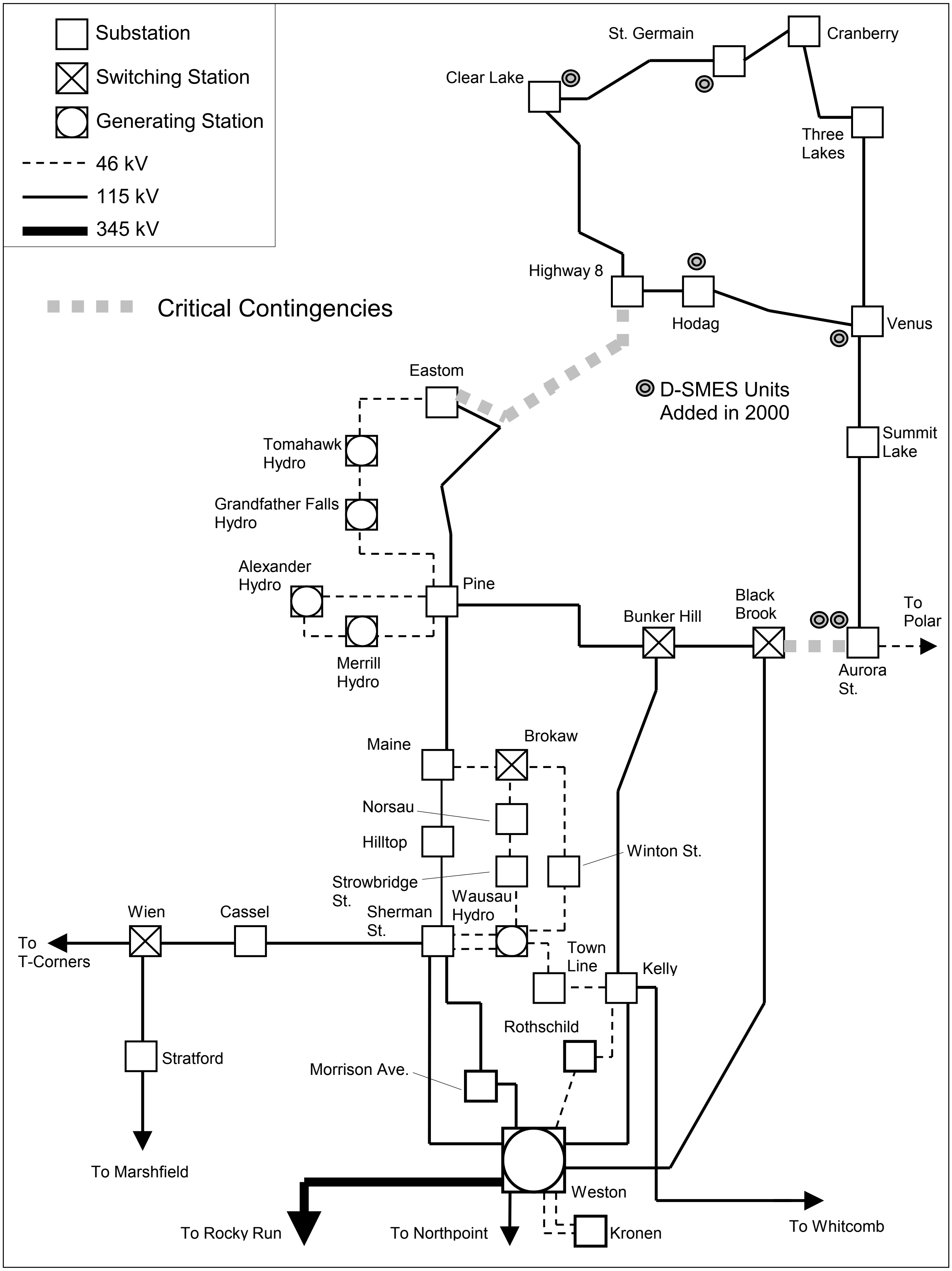


Figure D-7: Sample Dynamic Load Model – Highway 8 241

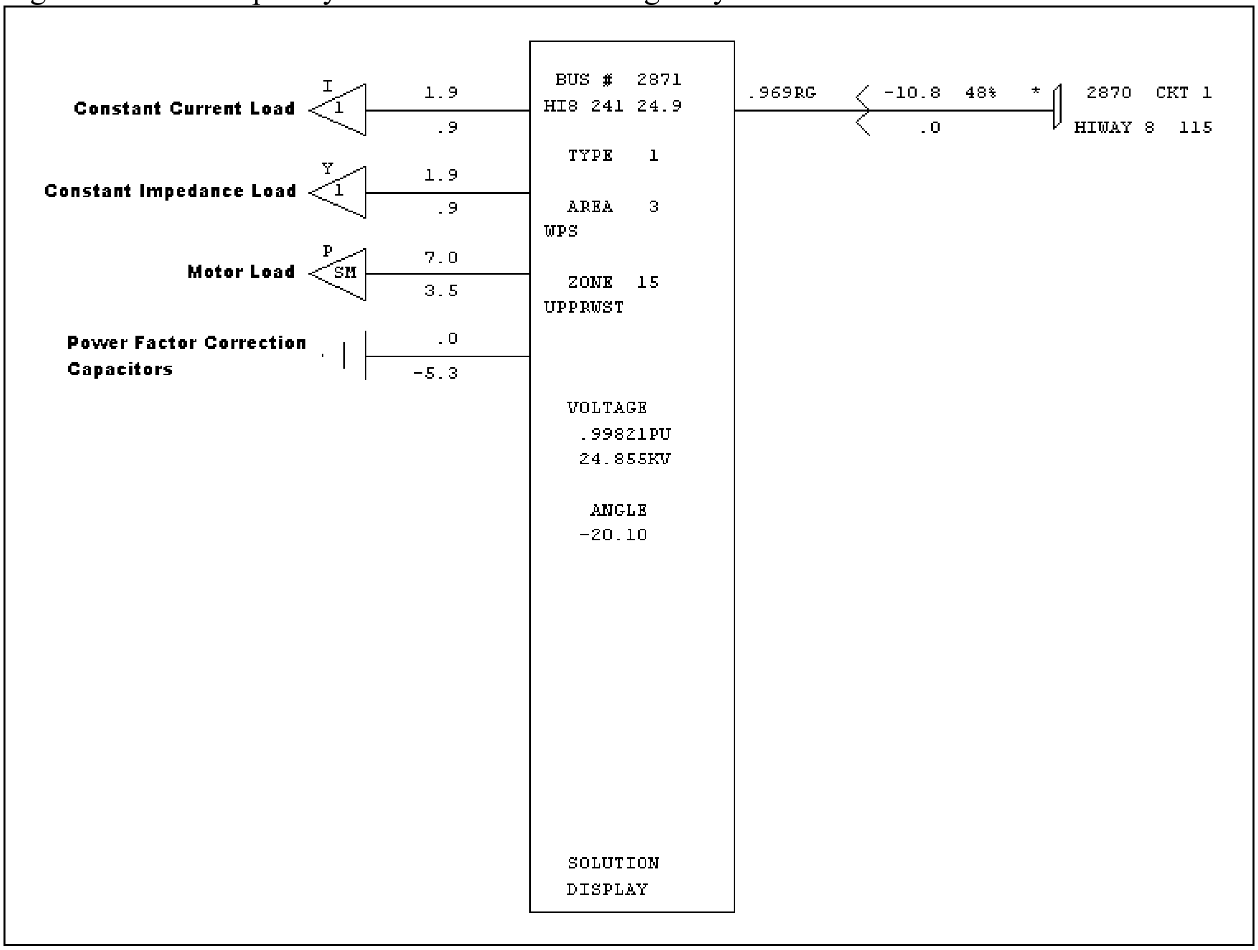


Figure D-8: Summer 2001 – Upper West Load Flow Diagram.

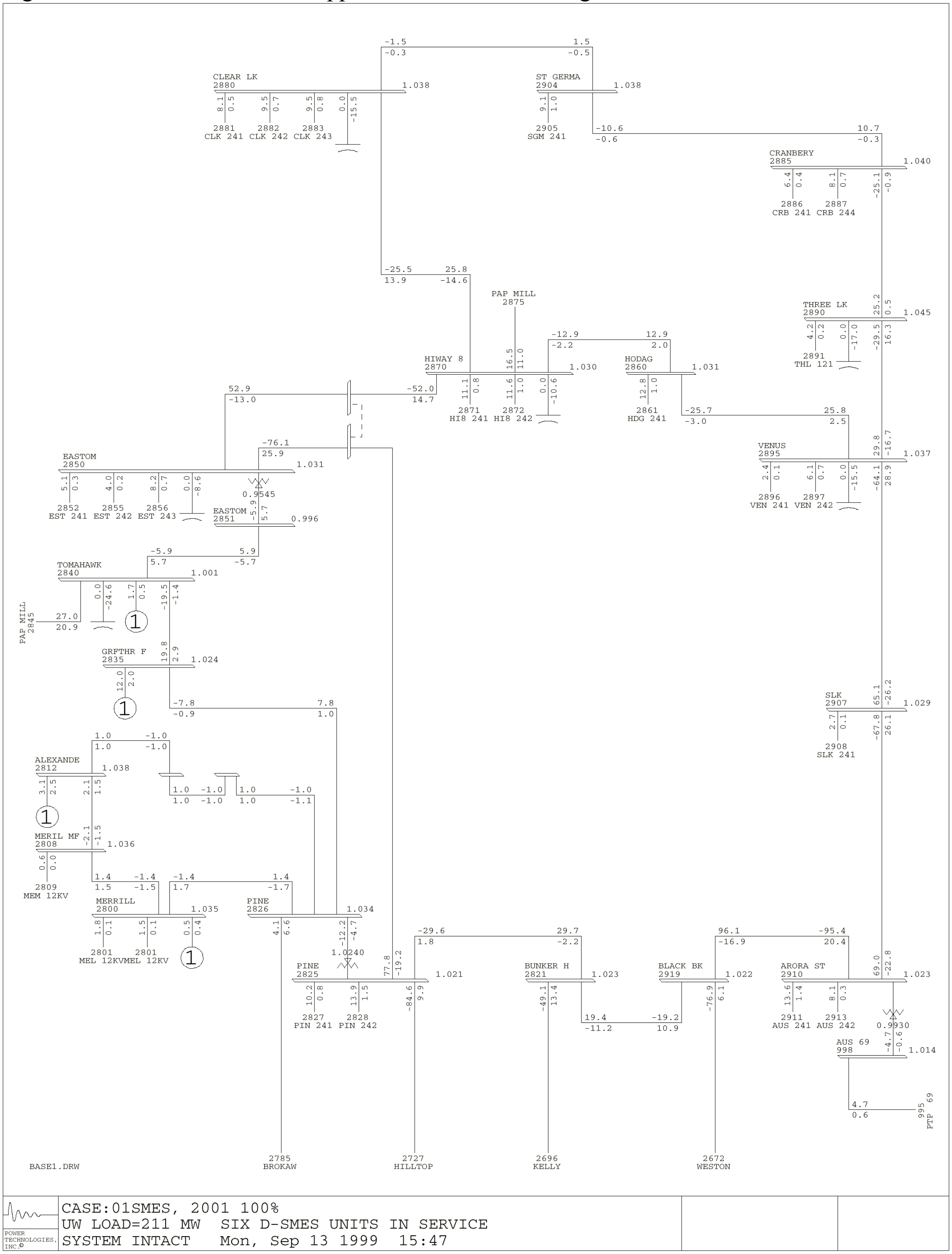


Figure D-9: Summer 2002 Upper West Load Flow Diagram.

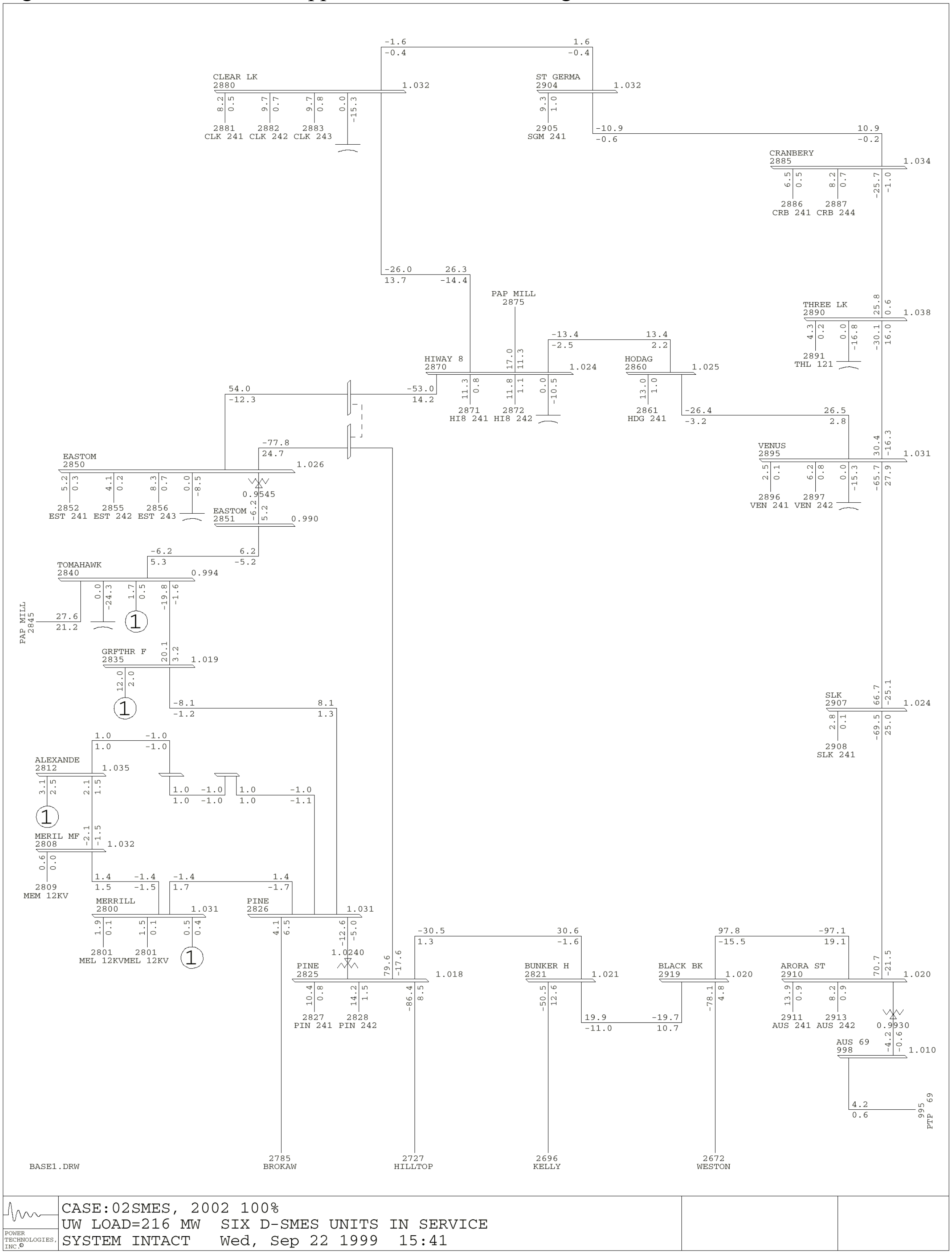


Figure D-10: Summer 2003 Upper West Load Flow Diagram.

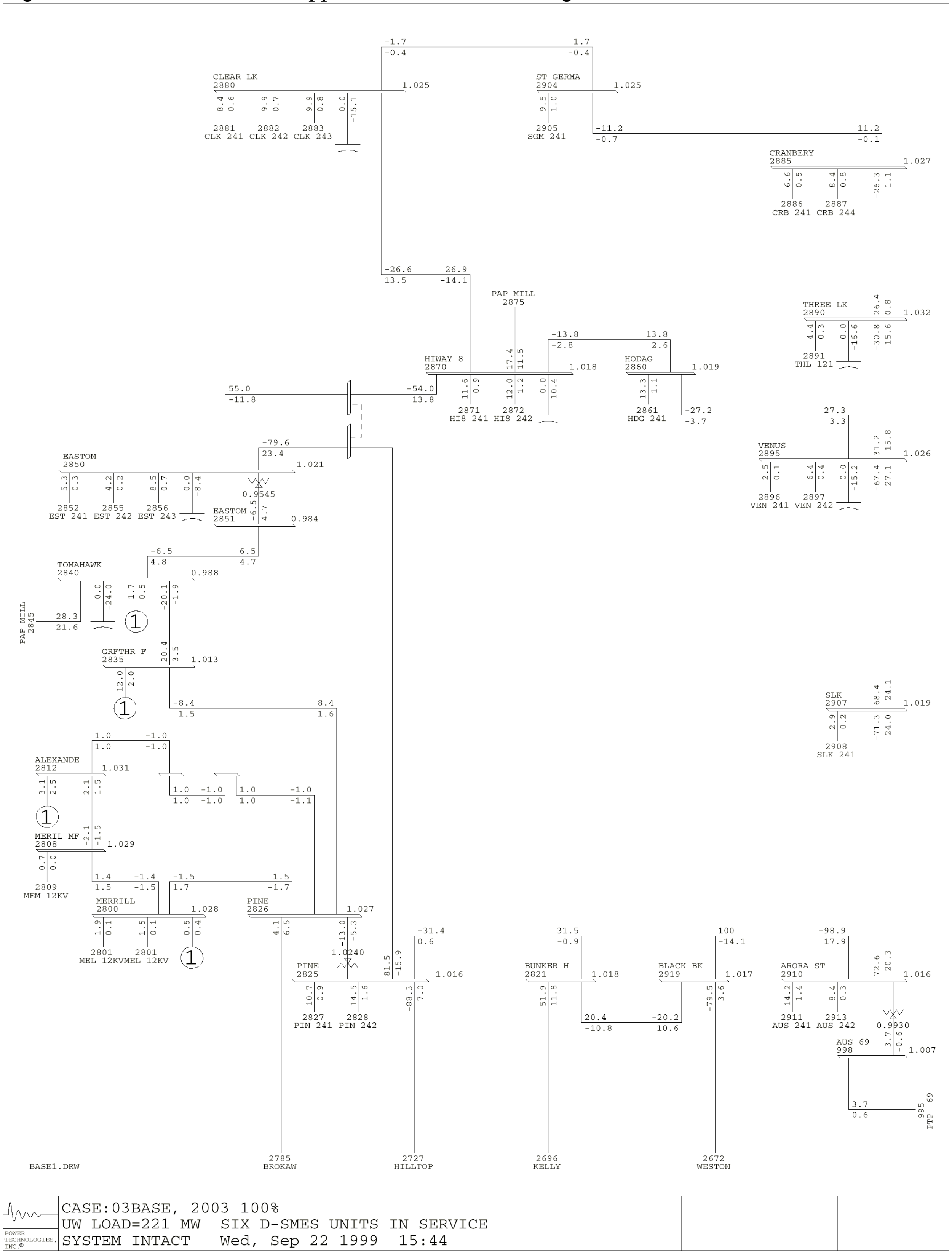


Figure D-11: Upper West Transmission System Response to a BlackBrook—Aurora St. Fault.

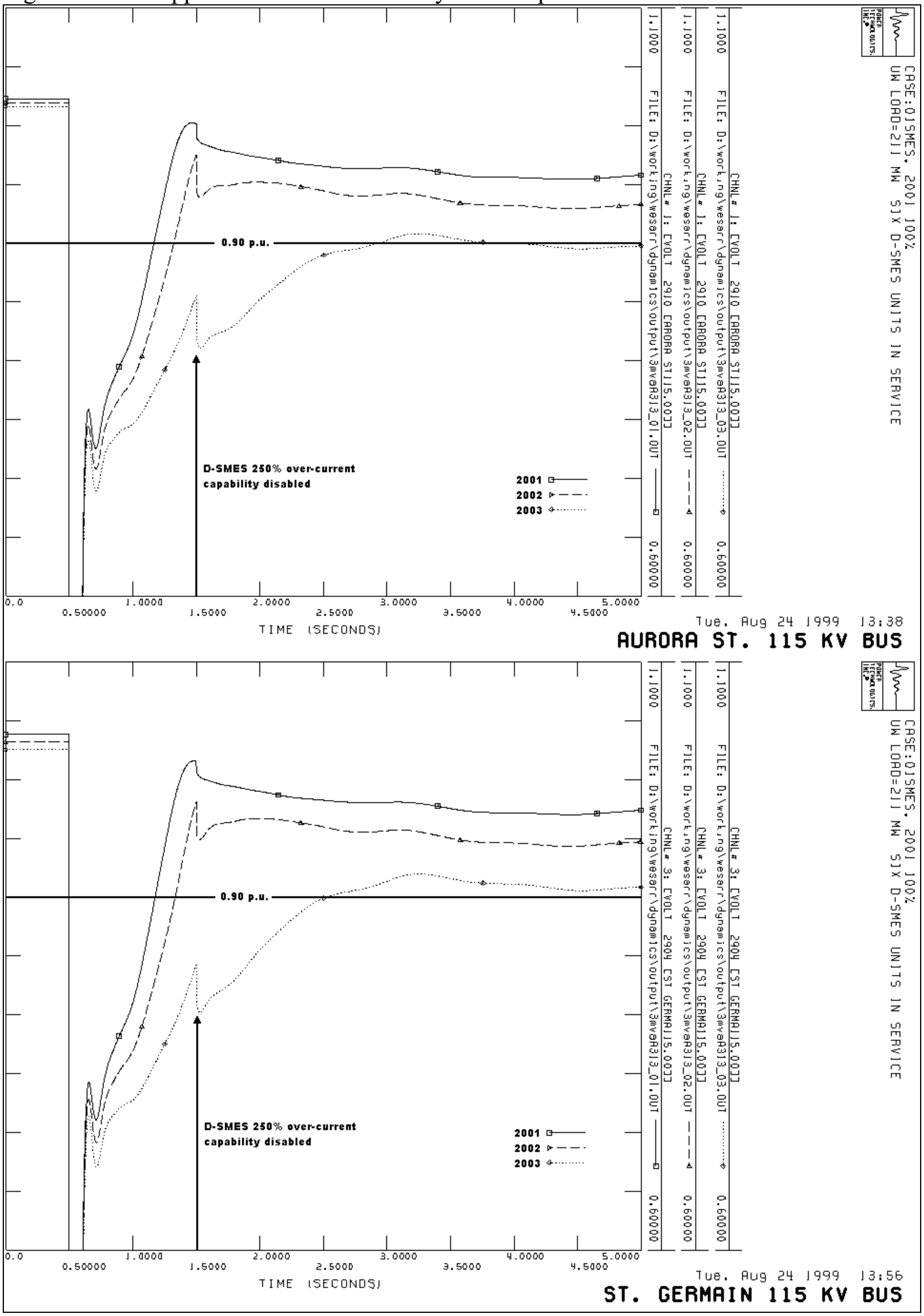


Figure D-12: Aurora St. D-SMES Response (2 units).
2003 Summer, Black Brook-Aurora St. Fault.

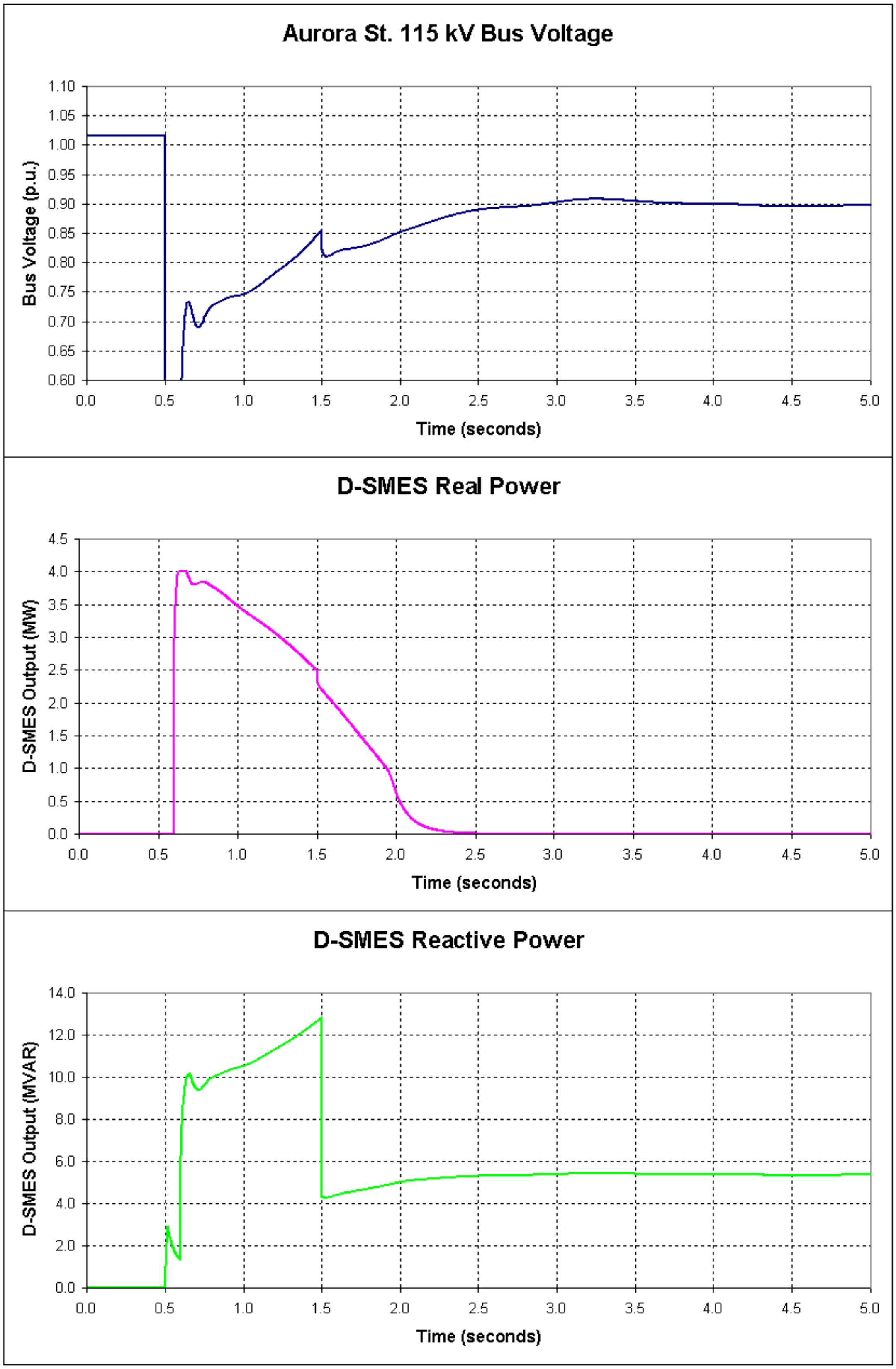


Figure D-13: Venus D-SMES Response (1 unit).
2003 Summer, Black Brook—Aurora St. Fault.

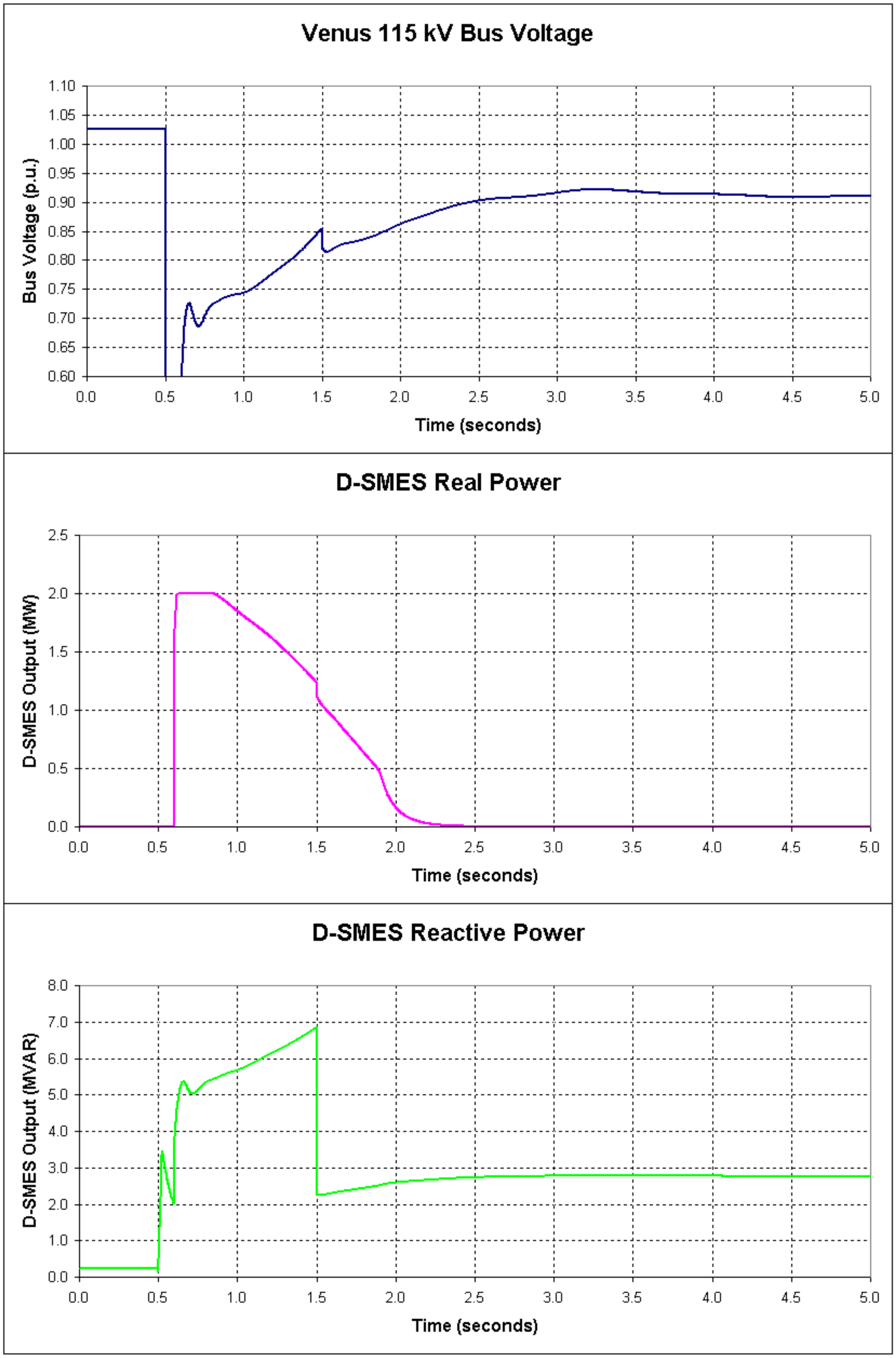


Figure D-14: Hodag D-SMES Response (1 unit).
2003 Summer, Black Brook—Aurora St. Fault.

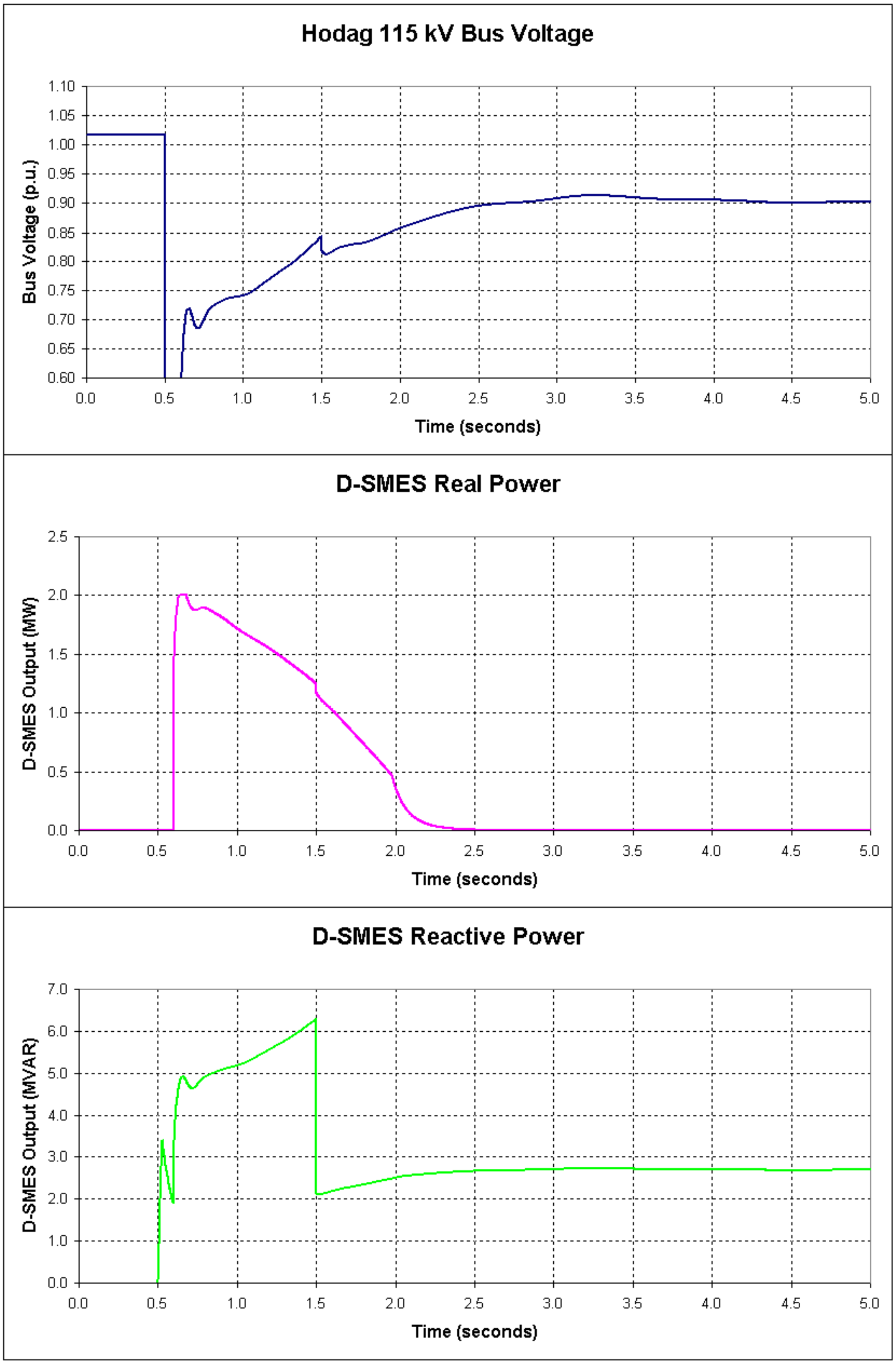


Figure D-15: Clear Lake D-SMES Response (1 unit).
2003 Summer, Black Brook—Aurora St. Fault.

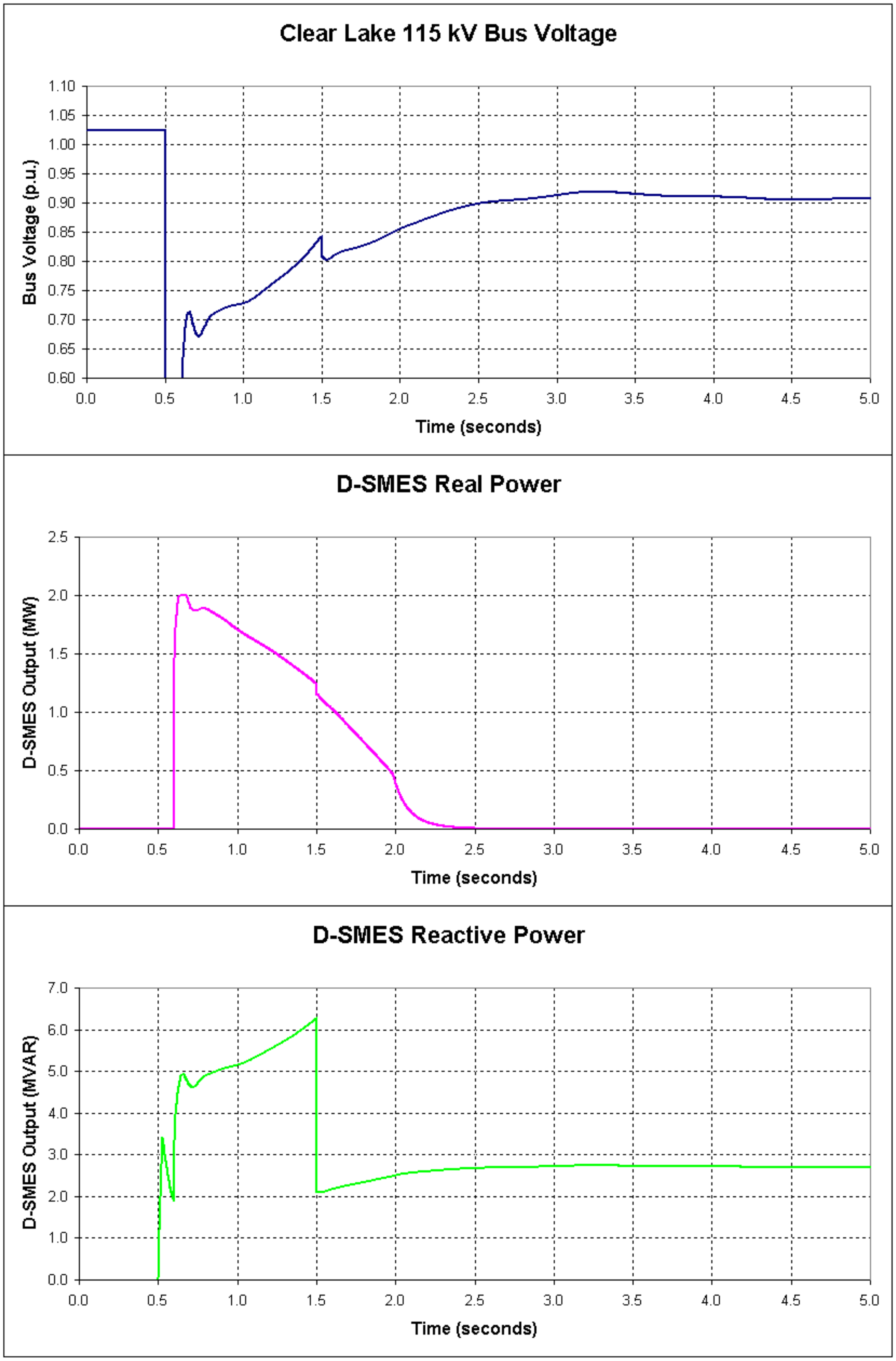


Figure D-16: St. Germain D-SMES Response (1 unit).
2003 Summer, Black Brook—Aurora St. Fault.

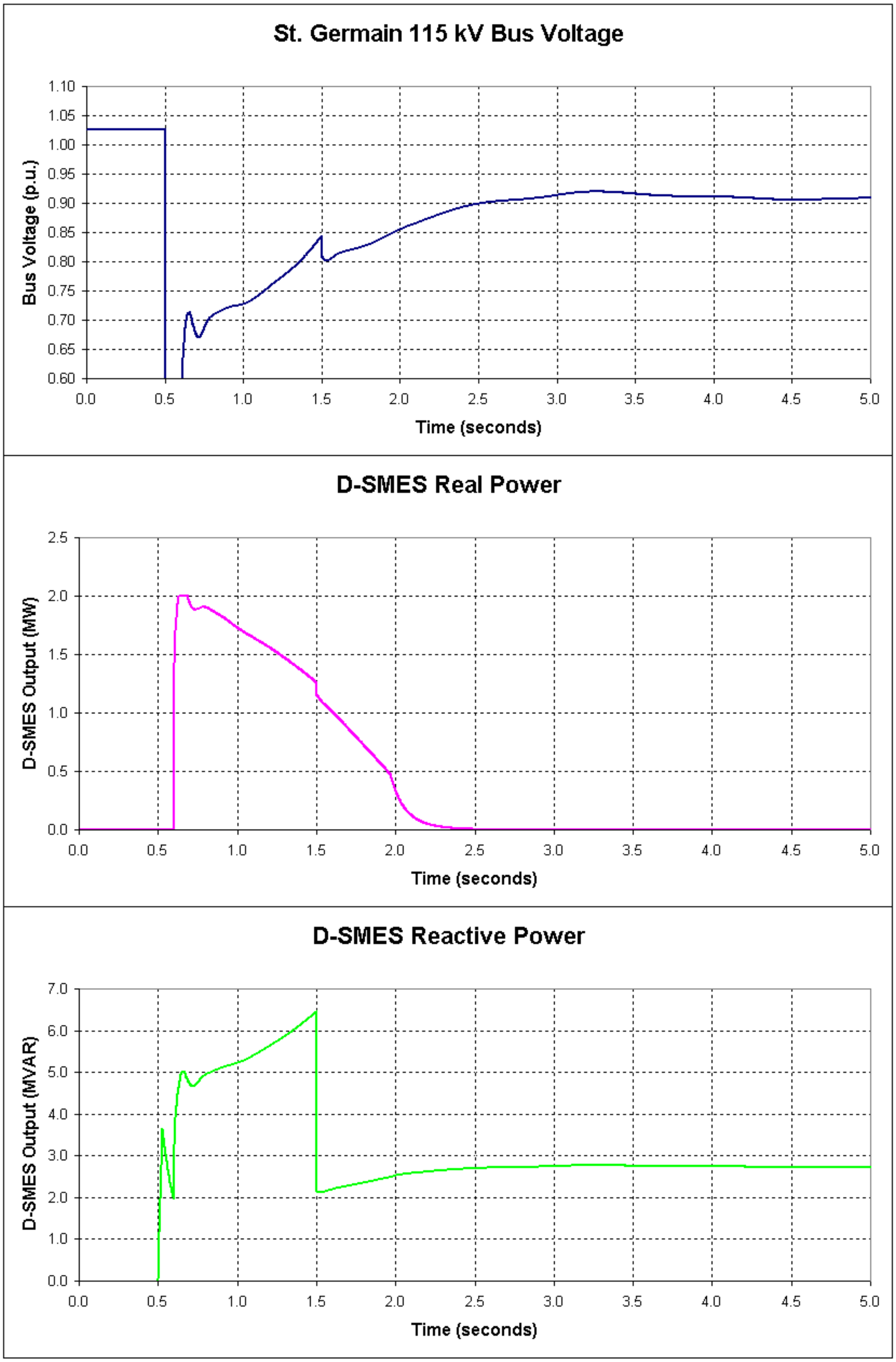


Figure D-17: Wausau 46 kV Conversion Steps.

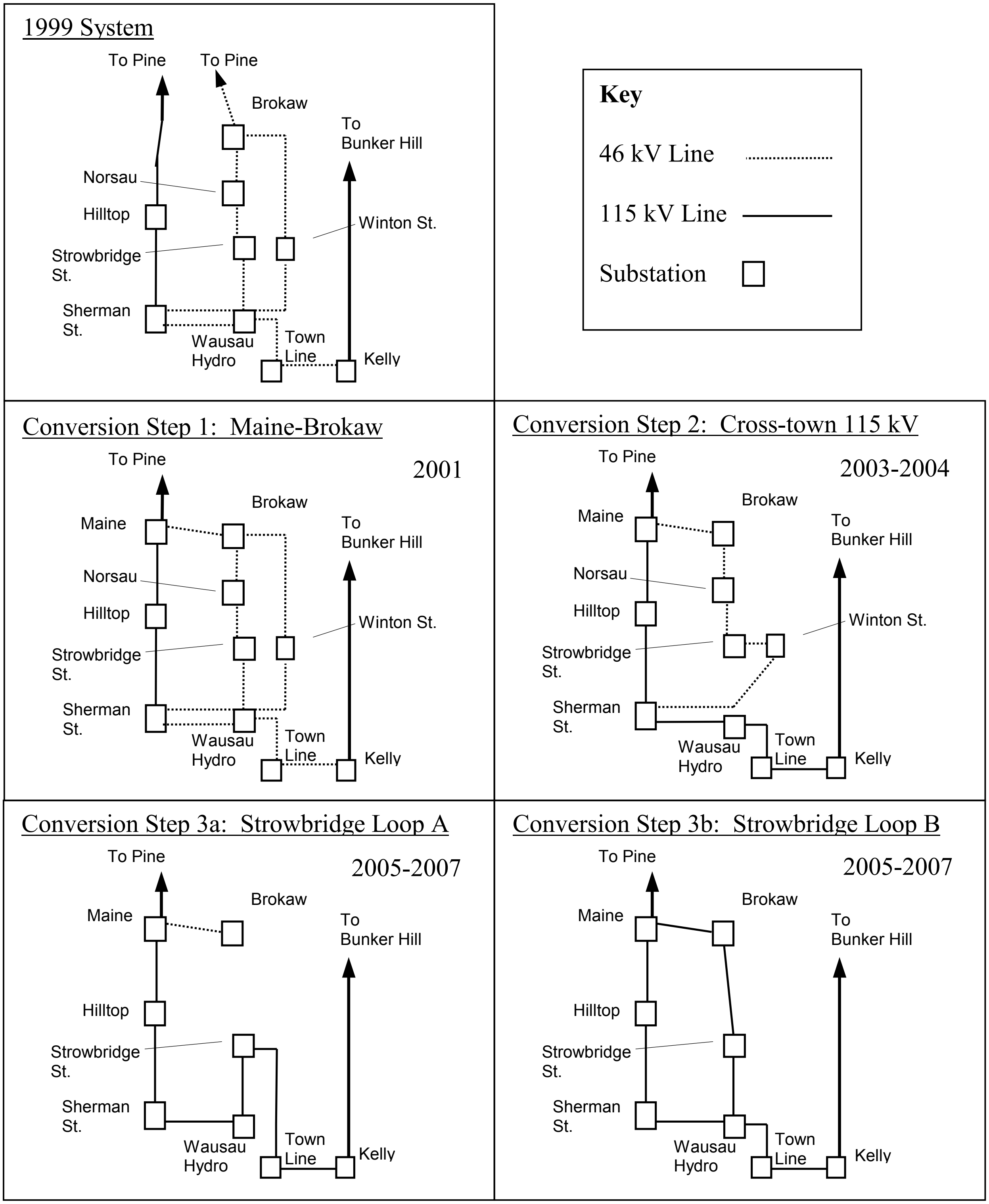


Figure D-18: Sherman St.-Hilltop Contingency – Wausau 46 kV Conversion Step 3a.

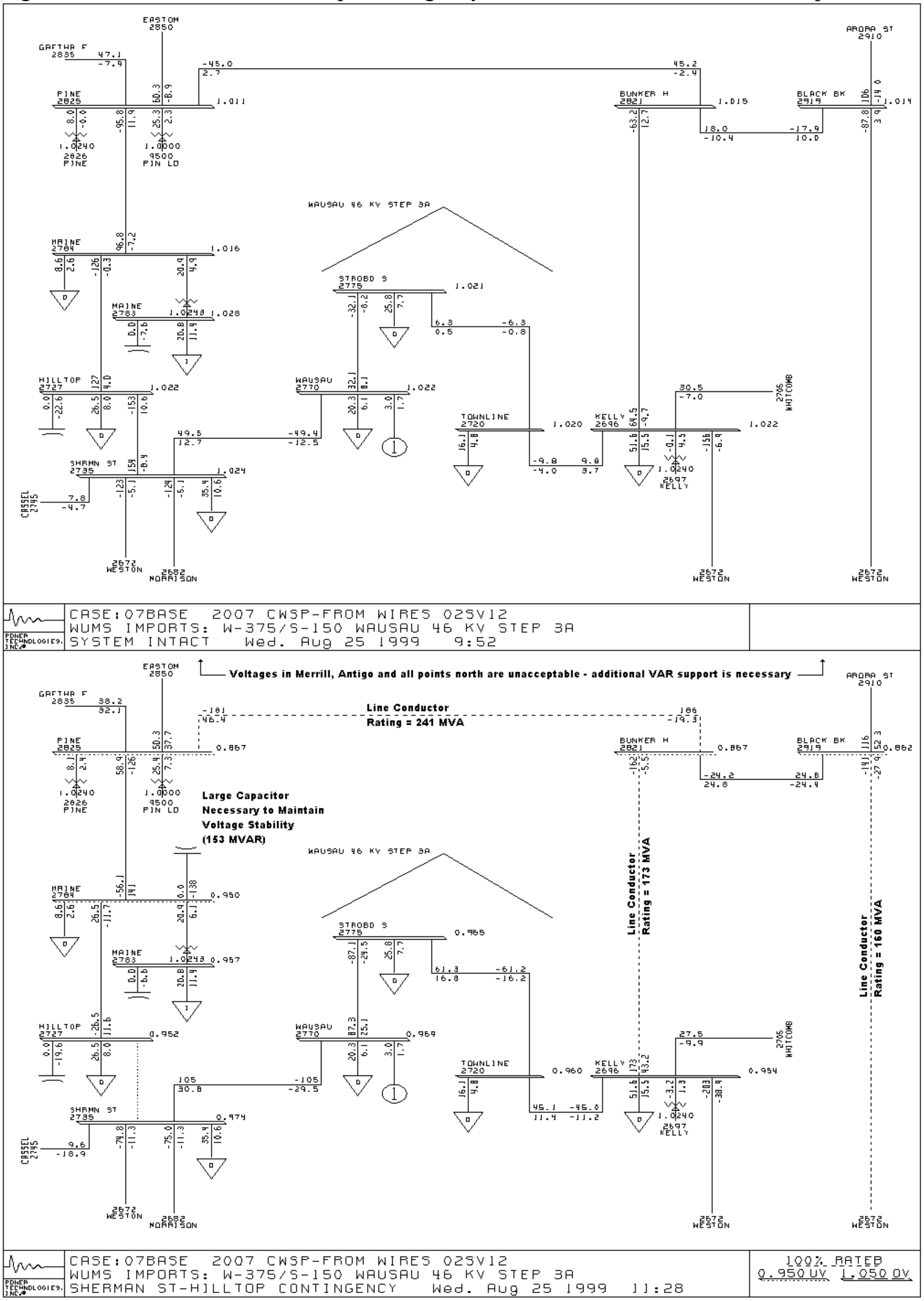


Figure D-19: Proposed 345 kV Corridors.

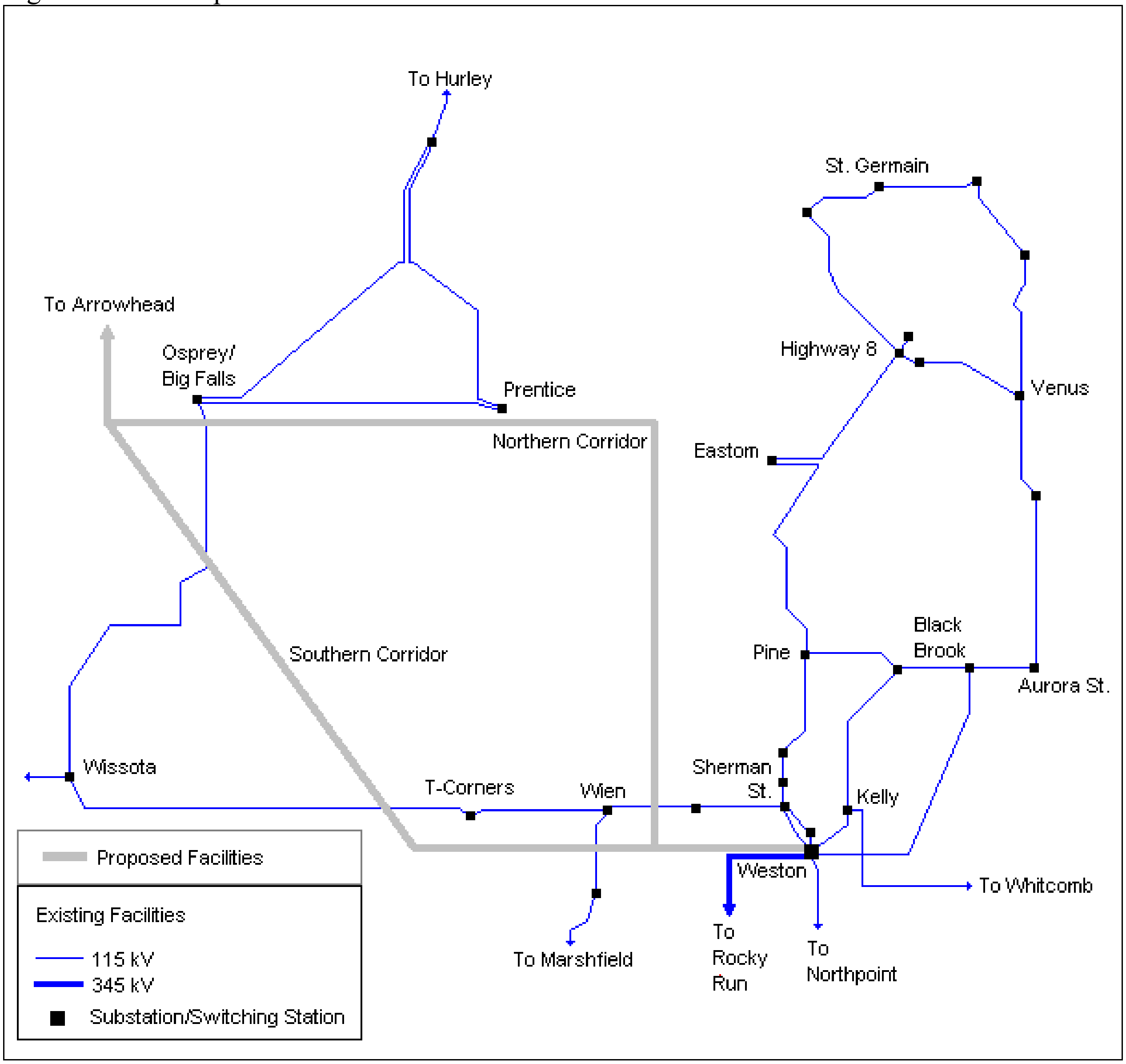


Figure D-20: Tripoli—Highway 8 Plan.

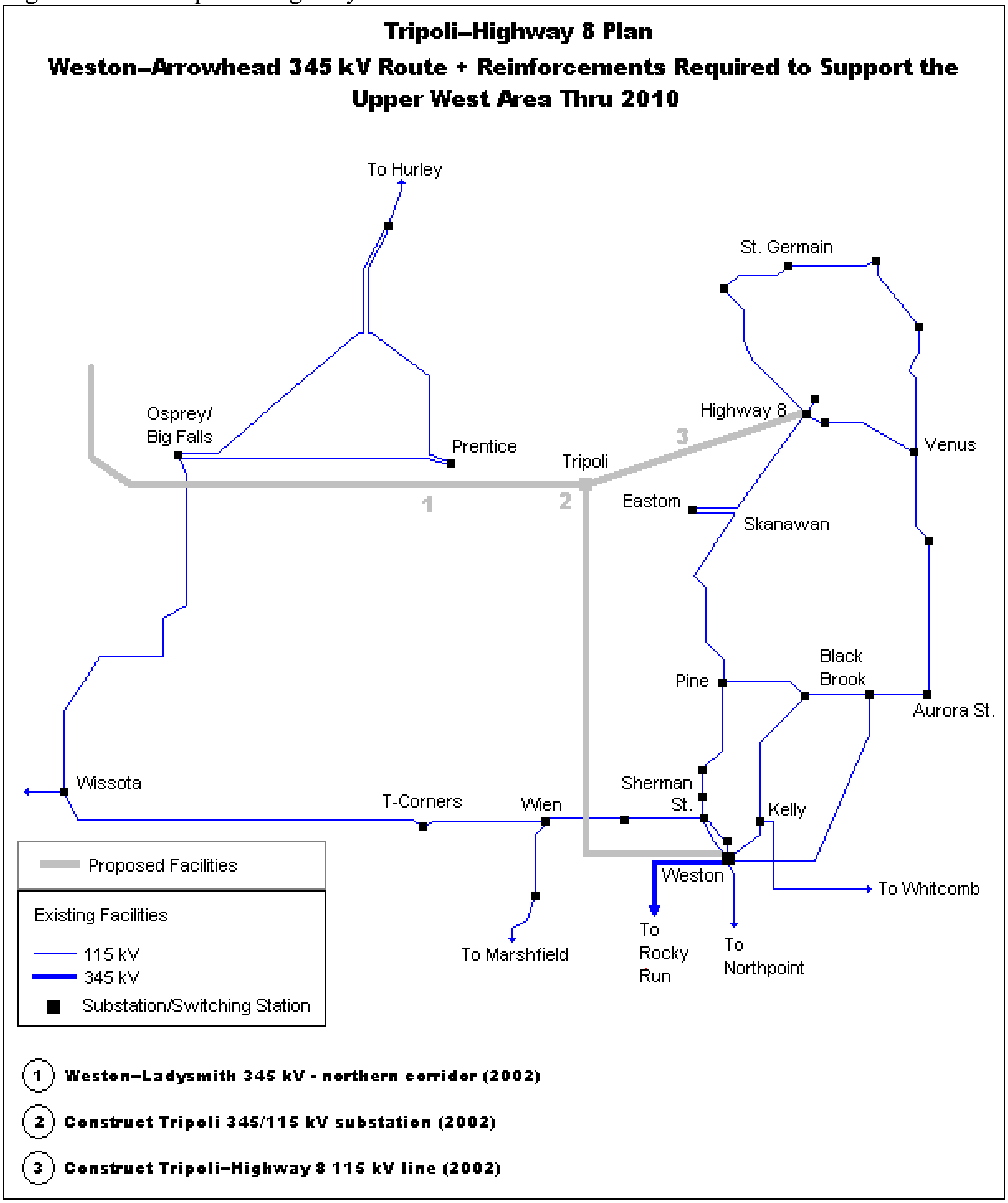
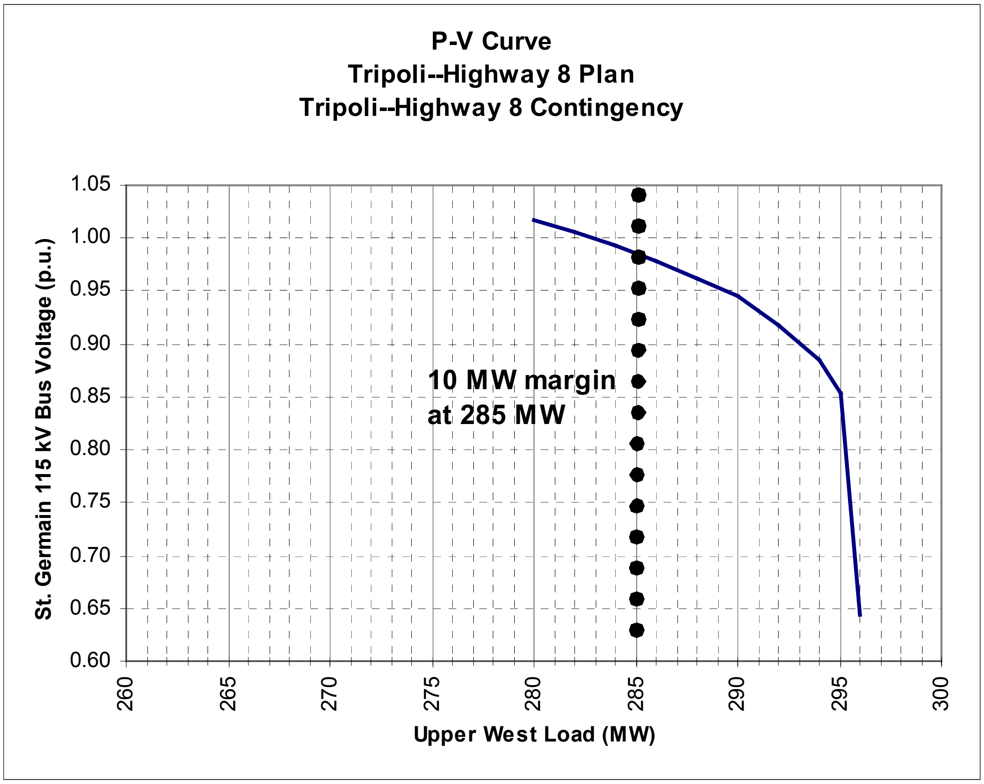


Figure D-21: Tripoli—Highway 8 Plan – P-V Curves.



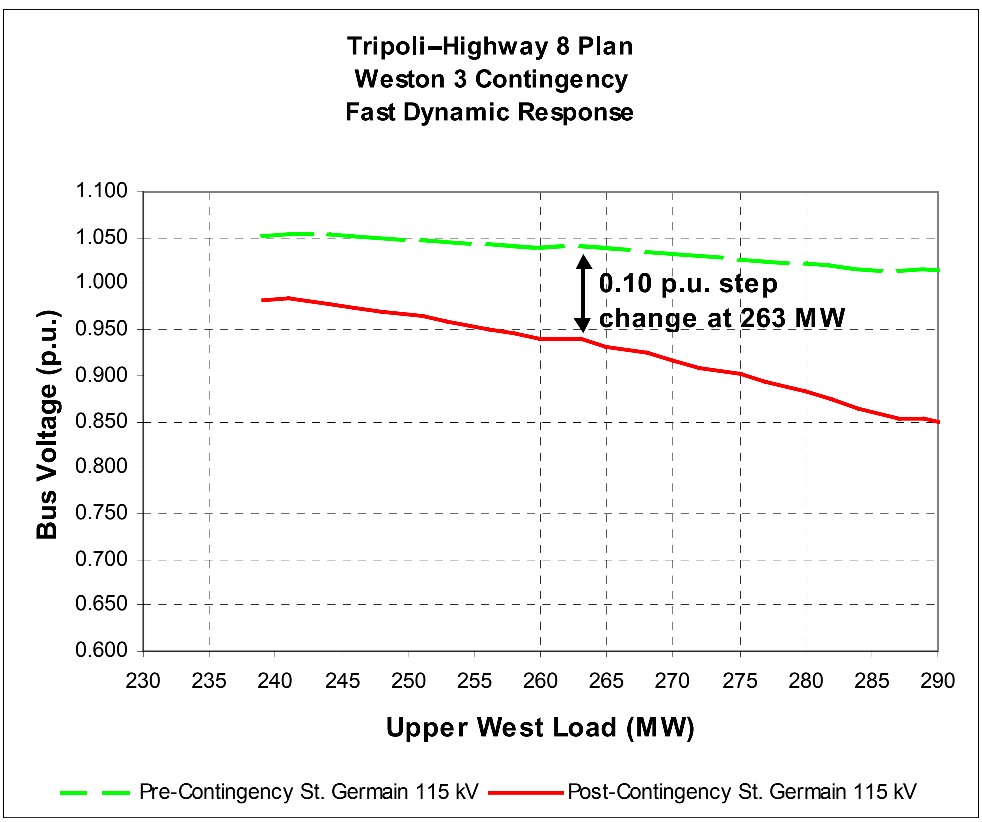


Figure D-22: D-SMES Plan.

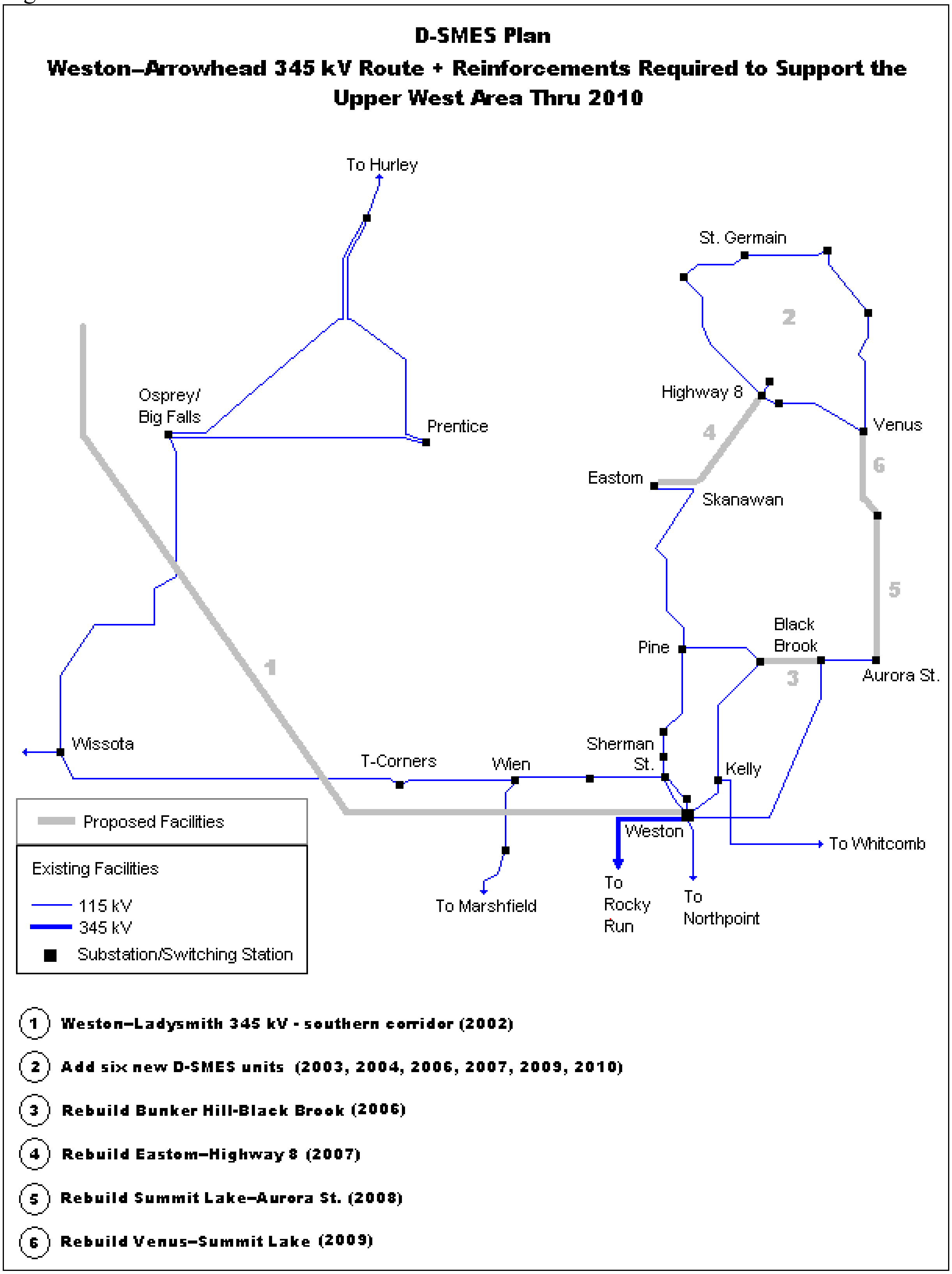


Figure D-23: Parallel Circuit Plan.

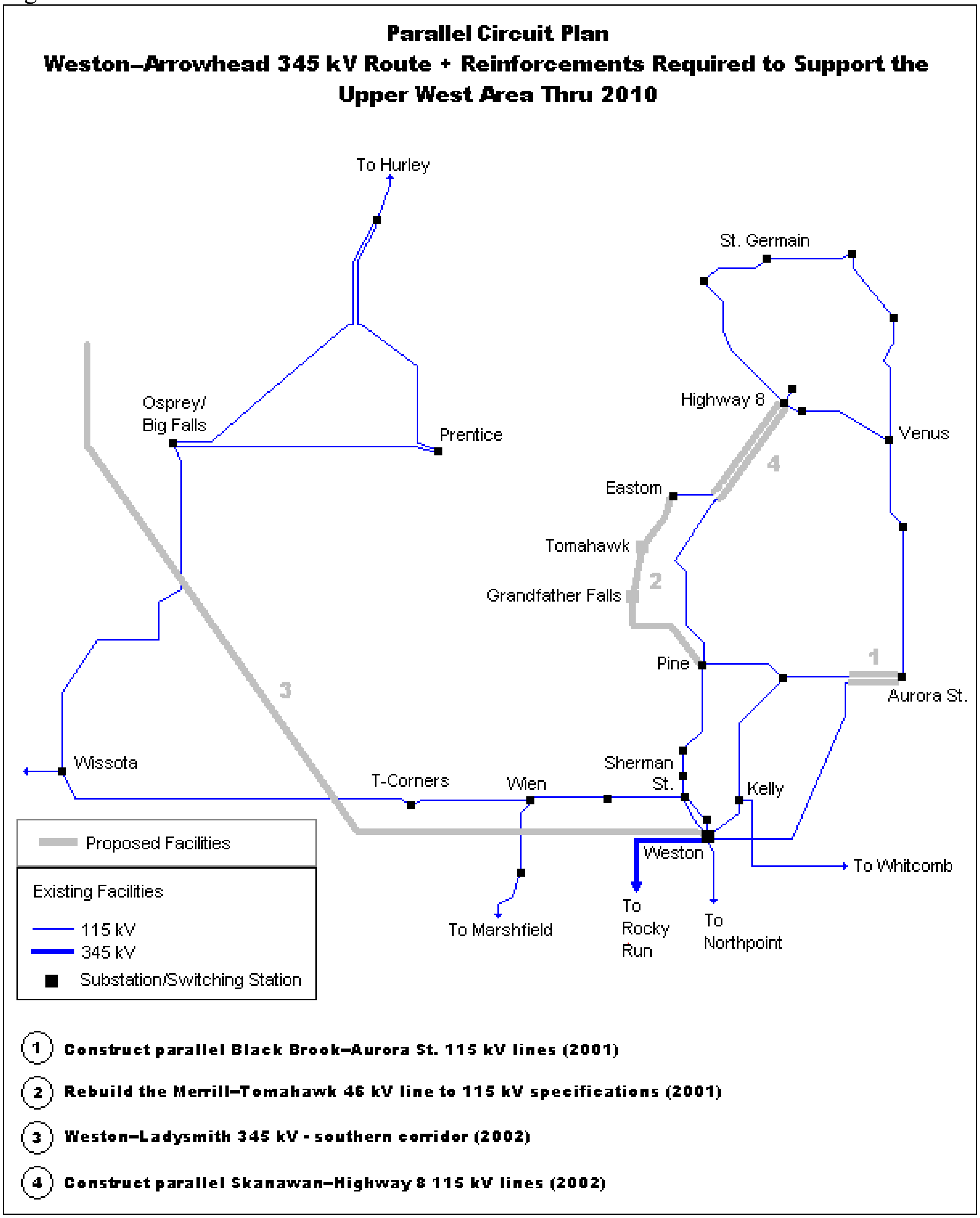
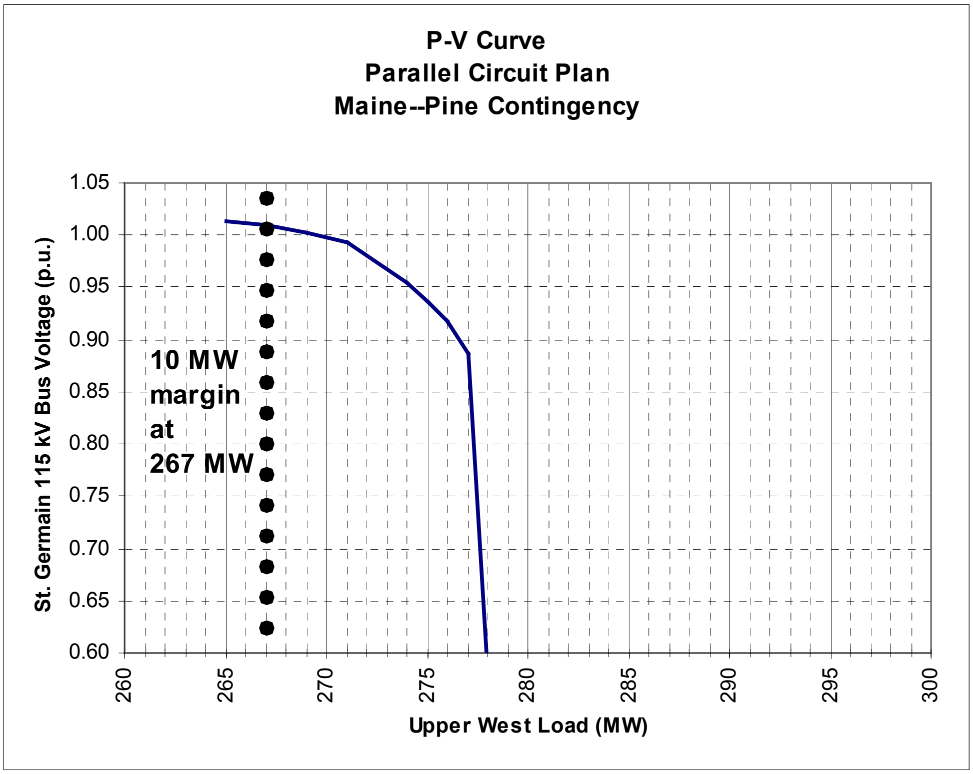


Figure D-24: Parallel Circuit Plan – P-V Curves.



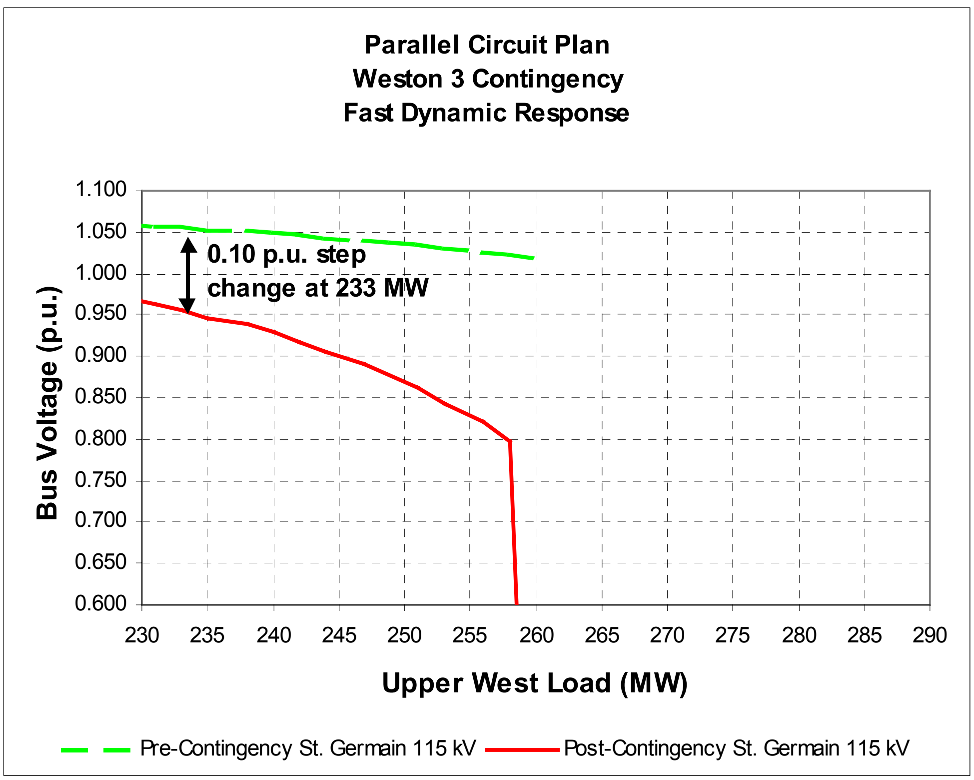


Figure D-25: Black Brook—Venus 345 kV Plan.

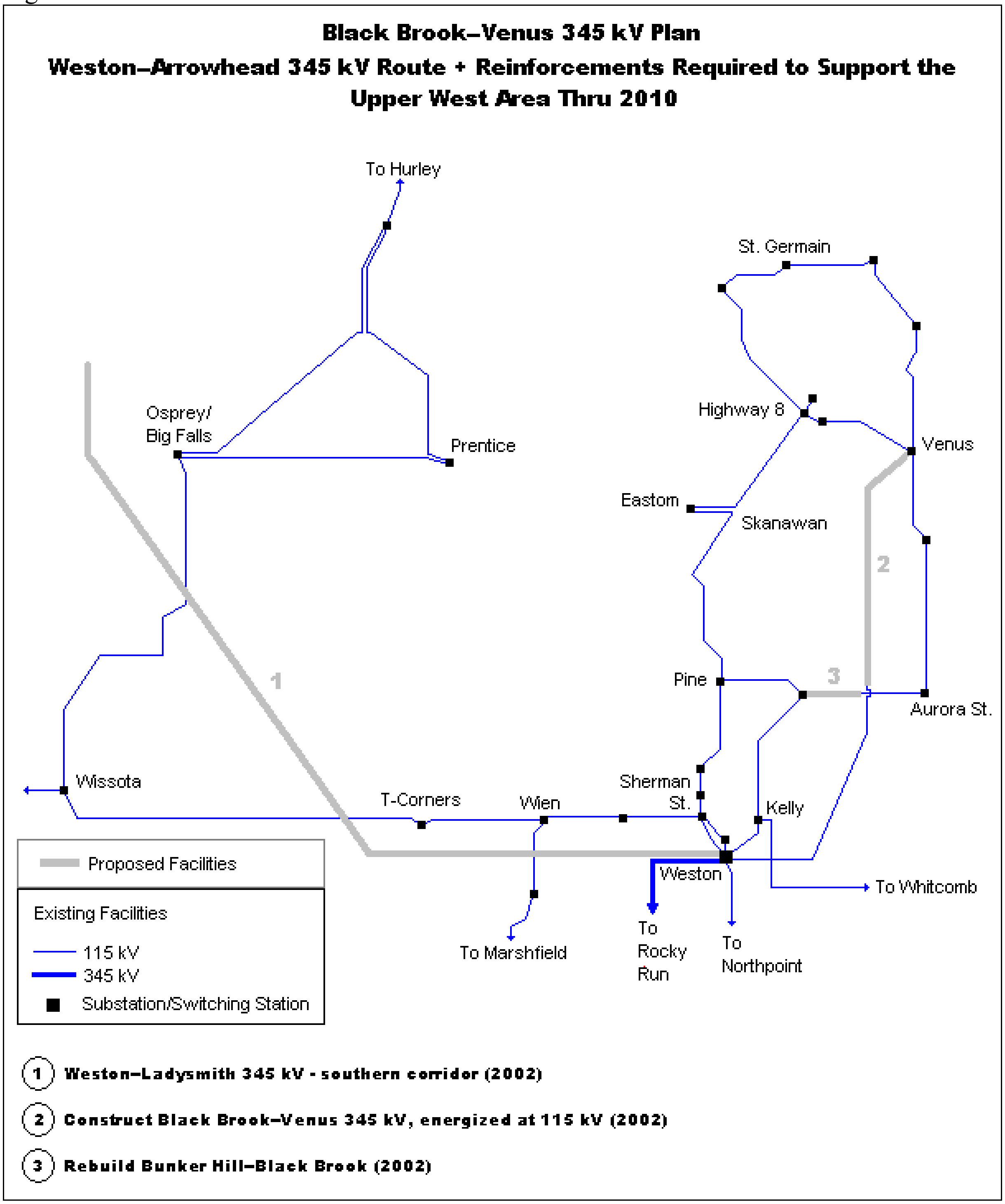
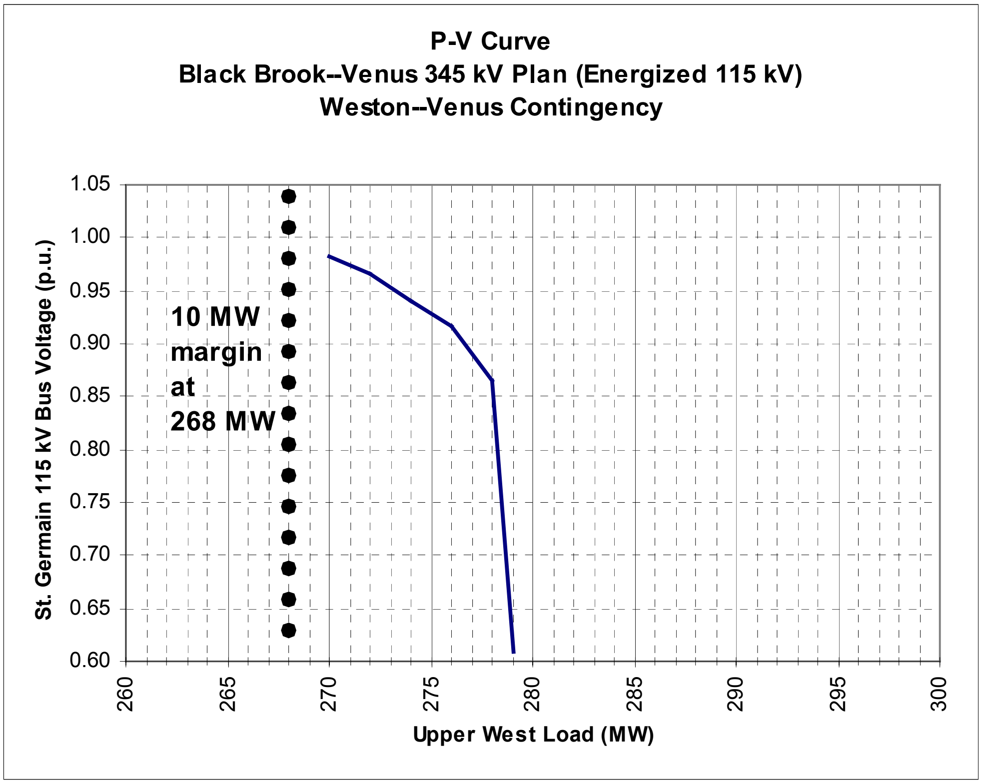


Figure D-26: Black Brook—Venus 345 kV Plan – P-V Curves.



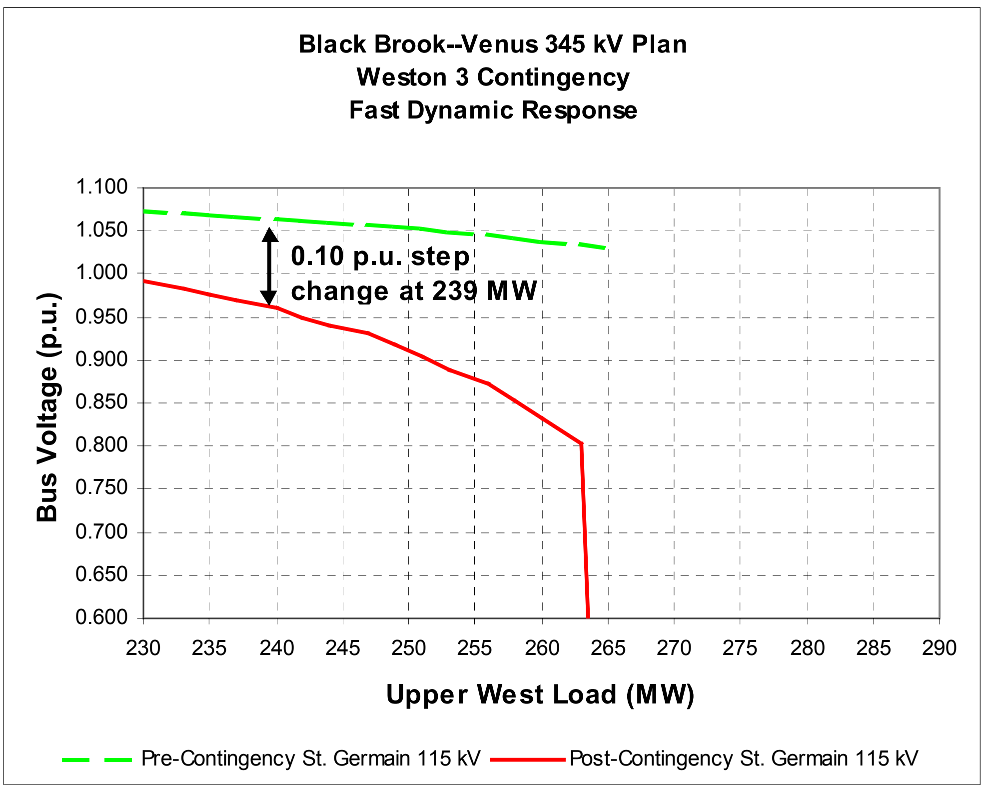


Figure D-27: Black Brook—Venus 115 kV Plan.

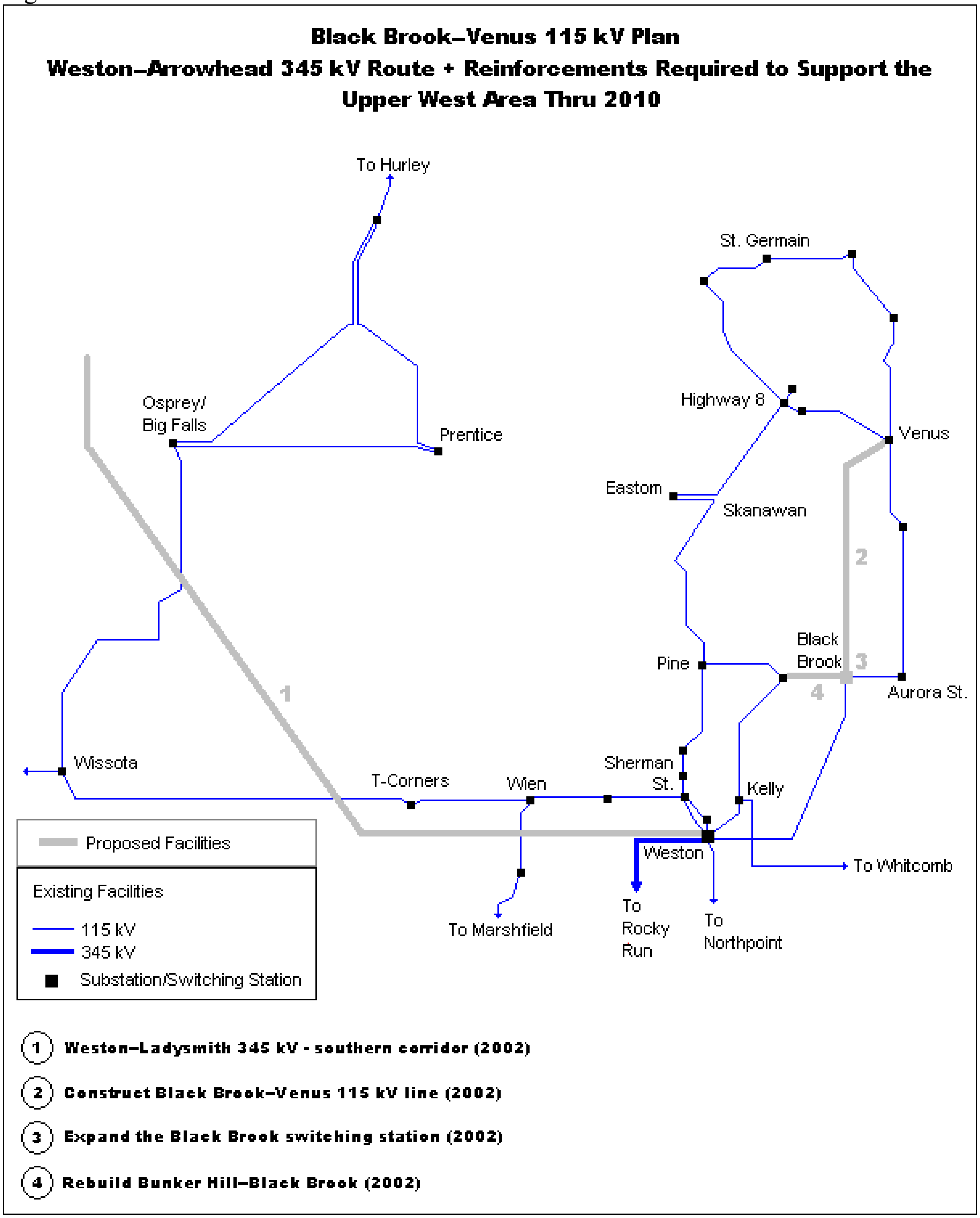
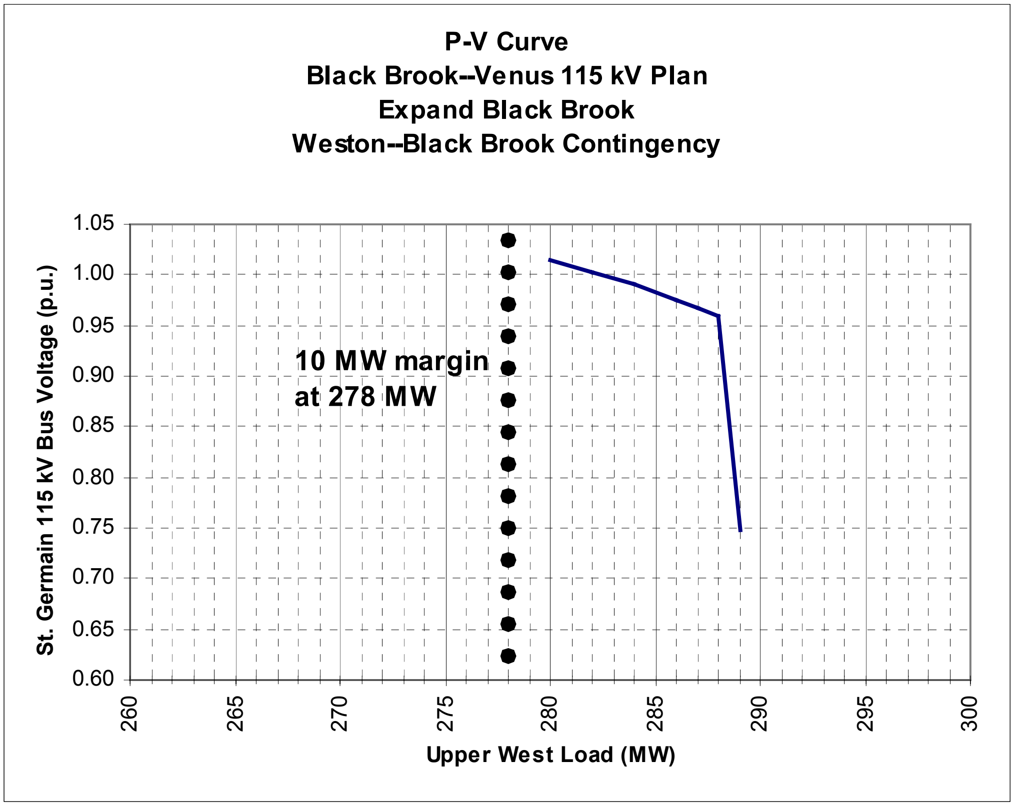


Figure D-28: Black Brook—Venus 115 kV Plan – P-V Curves.



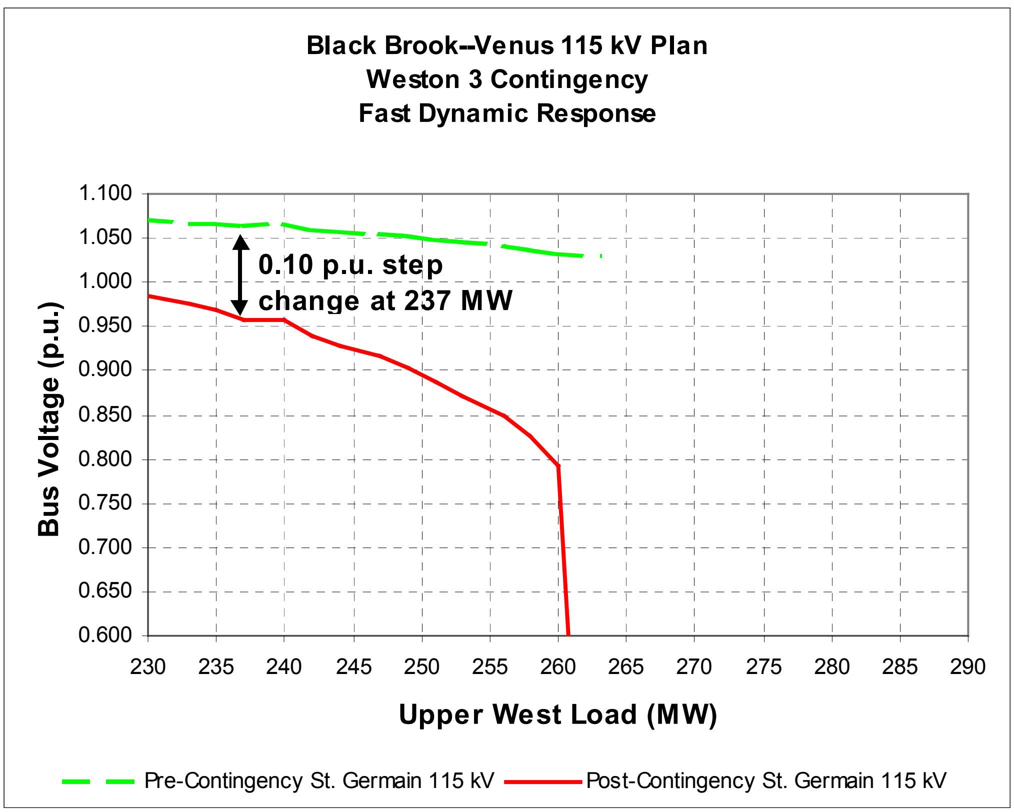


Figure D-29: Prentice—Highway 8 Plan.

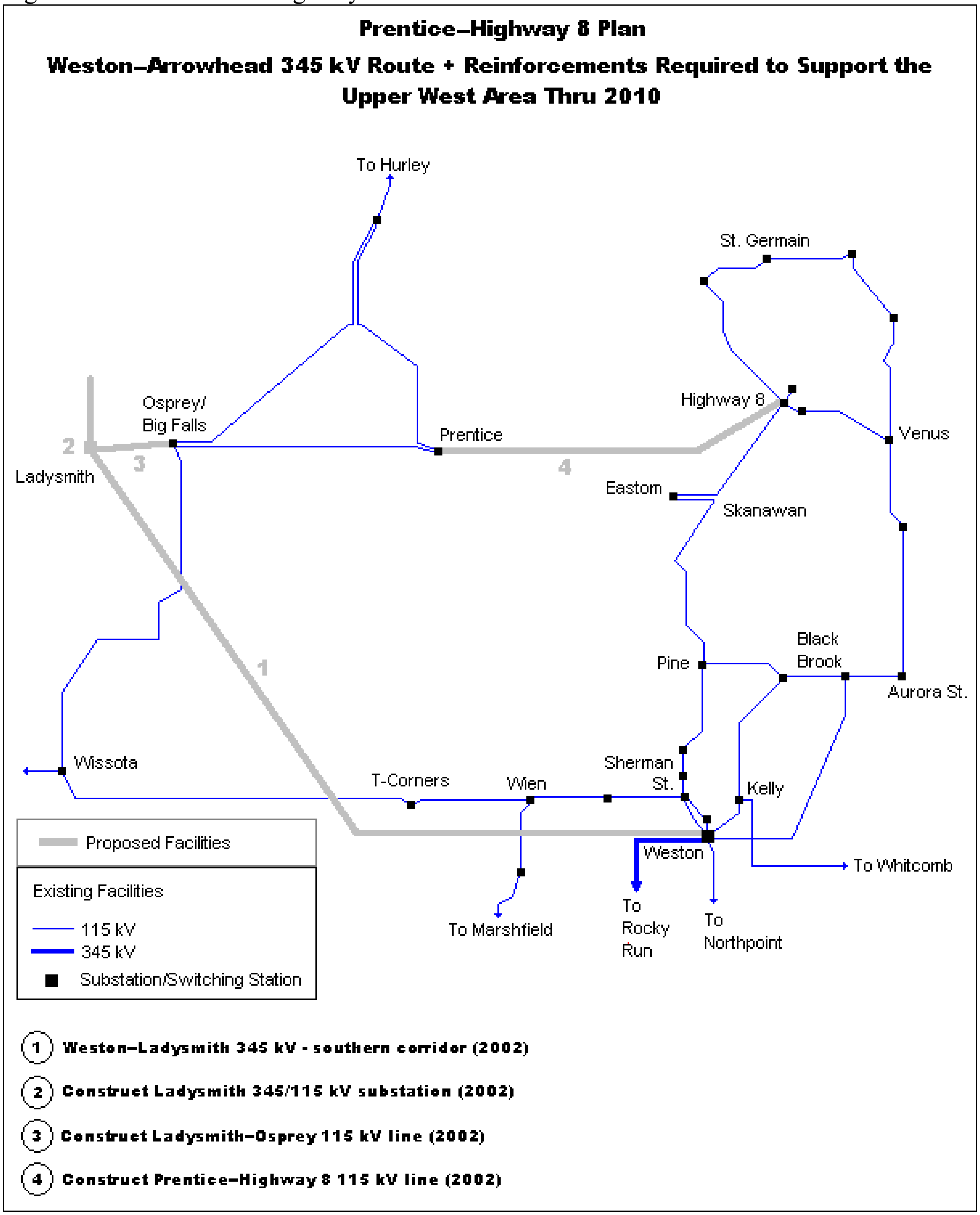


Figure D-30: Prentice—Highway 8 Plan – P-V Curves.